



THE UNIVERSITY *of* EDINBURGH

Edinburgh Research Explorer

Search for production of WW/WZ resonances decaying to a lepton, neutrino and jets in pp collisions at $\sqrt{s}=8$ TeV with the ATLAS detector

Citation for published version:

Clark, PJ, Leonidopoulos, C, Martin, VJ, Mills, C & Collaboration, A 2015, 'Search for production of WW/WZ resonances decaying to a lepton, neutrino and jets in pp collisions at $\sqrt{s}=8$ TeV with the ATLAS detector', *The European Physical Journal C (EPJ C)*, vol. C75, no. 5, Aad:2015ufa, pp. 370.
<https://doi.org/10.1140/epjc/s10052-015-3425-6>

Digital Object Identifier (DOI):

[10.1140/epjc/s10052-015-3425-6](https://doi.org/10.1140/epjc/s10052-015-3425-6)

Link:

[Link to publication record in Edinburgh Research Explorer](#)

Document Version:

Publisher's PDF, also known as Version of record

Published In:

The European Physical Journal C (EPJ C)

General rights

Copyright for the publications made accessible via the Edinburgh Research Explorer is retained by the author(s) and / or other copyright owners and it is a condition of accessing these publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy

The University of Edinburgh has made every reasonable effort to ensure that Edinburgh Research Explorer content complies with UK legislation. If you believe that the public display of this file breaches copyright please contact openaccess@ed.ac.uk providing details, and we will remove access to the work immediately and investigate your claim.



Search for production of WW/WZ resonances decaying to a lepton, neutrino and jets in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector

ATLAS Collaboration*

CERN, 1211 Geneva 23, Switzerland

Received: 17 March 2015 / Accepted: 22 April 2015 / Published online: 12 May 2015

© CERN for the benefit of the ATLAS collaboration 2015. This article is published with open access at Springerlink.com

Abstract A search is presented for narrow diboson resonances decaying to WW or WZ in the final state where one W boson decays leptonically (to an electron or a muon plus a neutrino) and the other W/Z boson decays hadronically. The analysis is performed using an integrated luminosity of 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8$ TeV collected by the ATLAS detector at the large hadron collider. No evidence for resonant diboson production is observed, and resonance masses below 700 and 1490 GeV are excluded at 95 % confidence level for the spin-2 Randall–Sundrum bulk graviton G^* with coupling constant of 1.0 and the extended gauge model W' boson respectively.

1 Introduction

Several new physics scenarios beyond the standard model (SM), such as technicolour [1–3], warped extra dimensions [4–6], and grand unified theories [7], predict new particles that predominantly decay to a pair of on-shell gauge bosons. In this paper, a search for such particles in the form of WW/WZ resonances where one W boson decays leptonically ($W \rightarrow \ell\nu$ with $\ell = e, \mu$) and the other W/Z boson decays hadronically ($W/Z \rightarrow q\bar{q}'/q\bar{q}$, with $q, q' = u, c, d, s$ or b) is presented. This search makes use of jet-substructure techniques for highly boosted W/Z bosons decaying hadronically and is optimized to significantly improve the sensitivity to high mass resonances compared to previous searches.

Two benchmark signal models are used to optimize the analysis strategy and interpret the search results. A spin-2 Kaluza–Klein (KK) graviton (G^*) is used to model a narrow resonance decaying to a WW final state. The KK graviton interpretation is based on an extended Randall–Sundrum model of a warped extra dimension (RS1) [8] where the SM fields can propagate into the bulk of the extra dimension. This extended “bulk” RS model, referred to as bulk

RS hereafter, avoids constraints on the original RS1 model from limits on flavour-changing neutral currents and electroweak precision tests, and has a dimensionless coupling constant $k/\bar{M}_{\text{Pl}} \sim 1$, where k is the curvature of the warped extra dimension and $\bar{M}_{\text{Pl}} = M_{\text{Pl}}/\sqrt{8\pi}$ is the reduced Planck mass. A spin-1 gauge boson (W') of the sequential standard model with modified coupling to WZ , also referred to as the extended gauge model (EGM) [7], is used to model a narrow resonance that decays to a WZ final state. The EGM introduces W' and Z' bosons with SM couplings to fermions and with the coupling strength of the heavy W' to WZ modified by a mixing factor $\xi = c \times (m_W/m_{W'})^2$ relative to the SM couplings, where m_W and $m_{W'}$ are the pole masses of the W and W' bosons respectively, and c is a coupling scaling factor. In this scenario the partial width of the W' boson scales linearly with $m_{W'}$, leading to a narrow resonance over the accessible mass range. The width of the W' resonance at 1 TeV is approximately 35 GeV.

Searches for these particles in several decay channels have been performed at the Tevatron and the large hadron collider (LHC) and are reported elsewhere [9–13]. Previous results from the ATLAS experiment in the $\ell\ell q\bar{q}$ channel excluded EGM W' bosons with masses up to 1.59 TeV for WZ final states and RS1 gravitons with $k/\bar{M}_{\text{Pl}} = 1$ and masses up to 740 GeV for ZZ final states [13]. The CMS experiment set limits on the production cross sections of bulk RS gravitons as well as excluded RS1 gravitons with $k/\bar{M}_{\text{Pl}} = 0.1$ for masses up to 1.2 TeV and W' bosons for masses up to 1.7 TeV [9].

This analysis is based on pp collision data at a centre-of-mass energy $\sqrt{s} = 8$ TeV corresponding to an integrated luminosity of 20.3 fb^{-1} collected by the ATLAS experiment at the LHC.

2 The ATLAS detector

The ATLAS detector [14] is a general-purpose particle detector used to investigate a broad range of physics processes. It

* e-mail: atlas.publications@cern.ch

includes inner tracking devices surrounded by a superconducting solenoid, electromagnetic and hadronic calorimeters and a muon spectrometer with a toroidal magnetic field. The inner detector (ID) provides precision tracking of charged particles with pseudorapidity $|\eta| < 2.5$.¹ The calorimeter system covers the pseudorapidity range $|\eta| < 4.9$. It is composed of sampling calorimeters with either liquid argon (LAr) or scintillator tiles as the active media. The muon spectrometer (MS) provides muon identification and measurement for $|\eta| < 2.7$. The ATLAS detector has a three-level trigger system to select events for offline analysis.

3 Monte Carlo samples

Simulated event samples are used to define the event selection and optimize the analysis. Benchmark signal samples are generated for a range of resonance masses from 300 to 2500 GeV in steps of 100 GeV. The bulk RS G^* signal events are generated with CalcHEP [15], using $k/\bar{M}_{\text{Pl}} = 1.0$, interfaced to PYTHIA8 [16] to model fragmentation and hadronization, and the EGM W' signal is generated using PYTHIA8 with $c = 1$. The factorization and renormalization scales are set to the generated resonance mass. The CTEQ6L1 [17] and MSTW2008LO [18] parton distribution functions (PDFs) are used for the G^* and W' signal samples respectively. The W' cross section is normalized to a next-to-next-to-leading-order (NNLO) calculation in α_s from ZWPROD [19].

Simulated event samples are used to model the shape and normalization of most SM background processes. The main background sources in the analysis arise from W bosons produced in association with jets ($W + \text{jets}$), followed by top-quark and multijet production, with smaller contributions from dibosons and $Z + \text{jets}$. Production of W and Z bosons in association with up to five jets is simulated using SHERPA 1.4.1 [20] with the CT10 PDFs [21], where b - and c -quarks are treated as massive particles. Samples generated with MC@NLO [22] and interfaced to HERWIG [23] for hadronization and to JIMMY [24] for the underlying event are used for $t\bar{t}$ production as well as for single top-quark production in the s -channel and the Wt process. The $t\bar{t}$ cross section is normalized to the calculation at NNLO in QCD including resummation of next-to-next-to-leading logarithmic soft gluon terms with Top++2.0 [25–31]. Single top-quark production in the t -channel is simulated with ACERMC [32]

interfaced to PYTHIA6 [33]. Diboson samples (WW , WZ and ZZ) are generated with HERWIG and JIMMY.

The effect of multiple pp interactions in the same and neighbouring bunch crossings (pile-up) is included by overlaying minimum-bias events simulated with PYTHIA8 on each generated signal and background event. The number of overlaid events is such that the distribution of the average number of interactions per pp bunch crossing in the simulation matches that observed in the data (on average 21 interactions per bunch crossing). The generated samples are processed through the GEANT4-based detector simulation [34,35] or a fast simulation using a parameterization of the performance of the calorimeters and GEANT4 for the other parts of the detector [36], and the standard ATLAS reconstruction software used for collision data.

4 Event selection

Events are required to have a vertex with at least three associated tracks, each with transverse momentum $p_T > 400$ MeV. The primary vertex is chosen to be the reconstructed vertex with the largest track $\sum p_T^2$.

The main physics objects used in this analysis are electrons, muons, jets and missing transverse momentum. Electrons are selected from clusters of energy depositions in the calorimeter that match a track reconstructed in the ID and satisfy “tight” identification criteria defined in Ref. [37]. The electrons are required to have transverse momentum $p_T > 25$ GeV and $|\eta| < 2.47$, excluding the transition region between the barrel and endcaps in the LAr calorimeter ($1.37 < |\eta| < 1.52$). Muons are reconstructed by combining ID and MS tracks that have consistent trajectories and curvatures [38]. The muon tracks are required to have $p_T > 25$ GeV and $|\eta| < 2.5$. In addition, leptons are required to be isolated from other tracks and calorimetric activity. The scalar sum of transverse momenta of tracks with $p_T > 1$ GeV within $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} = 0.2$ around the lepton track is required to be $< 15\%$ of the lepton p_T . Similarly, the sum of transverse energy deposits in the calorimeter within a cone of $\Delta R = 0.2$, excluding the transverse energy from the lepton and corrected for the expected pile-up contribution, is required to be $< 14\%$ of the lepton p_T . In order to ensure that leptons originate from the interaction point, a requirement of $|d_0|/\sigma_{d_0} < 6$ (3.5) and $|z_0 \sin \theta| < 0.5$ mm is imposed on the electrons (muons), where $d_0(z_0)$ is the transverse (longitudinal) impact parameter of the lepton with respect to the reconstructed primary vertex and σ_{d_0} is the uncertainty on the measured d_0 .

In this analysis, jets are reconstructed from three-dimensional clusters of energy depositions in the calorimeter using two different algorithms. The jet constituents are considered massless. The low- p_T hadronically decaying W/Z

¹ ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point (IP) in the centre of the detector and the z -axis along the beam pipe. The x -axis points from the IP to the centre of the LHC ring, and the y -axis points upward. Cylindrical coordinates (r , ϕ) are used in the transverse plane, ϕ being the azimuthal angle around the beam pipe. The pseudorapidity is defined in terms of the polar angle θ as $\eta = -\ln \tan(\theta/2)$.

candidates are selected by combining the two highest- p_T jets which are constructed by the anti- k_t algorithm [39] with a distance parameter of $R = 0.4$. These jets are referred to as small- R jets and denoted by “ j ” hereafter. The energy of small- R jets is corrected for losses in passive material, the non-compensating response of the calorimeter, and extra energy due to multiple pp interactions [40]. The small- R jets are required to have $p_T > 30$ GeV and $|\eta| < 2.8$. For jets with $p_T < 50$ GeV, the summed scalar p_T of associated tracks from the reconstructed primary vertex is required to be at least 50 % of the summed scalar p_T of all associated tracks. In the pseudorapidity range $|\eta| < 2.5$, jets containing hadrons from b -quarks are identified using the MV1 b -tagging algorithm [41] with an efficiency of 70 %, determined from $t\bar{t}$ simulated events, and with a misidentification rate for selecting light-quark or gluon jets of < 1 %.

For high- p_T W/Z bosons, such as the ones from a resonance with mass above 1 TeV, the hadronically decaying W/Z candidates are identified using a single large- R jet, referred to as “ J ” hereafter. The Cambridge–Aachen jet clustering algorithm [42] with a distance parameter of $R = 1.2$ is used. This jet algorithm offers the advantage of allowing the usage of a splitting and filtering algorithm similar to that described in Ref. [43] but optimized for the identification of highly boosted boson decays. To exploit the characteristics of the decay of massive bosons into a light-quark pair, the splitting and filtering algorithm used here does not impose a mass relation between the large- R jet and its subjects [44]. The momentum balance is defined as $\sqrt{y_f} = \min(p_T^{j1}, p_T^{j2})\Delta R_{12}/m_{12}$, where p_T^{j1} and p_T^{j2} are the transverse momenta of the two leading subjects, ΔR_{12} is their separation and m_{12} is their invariant mass. To suppress jets from gluon radiation and splitting, $\sqrt{y_f}$ is required to be > 0.45 . Furthermore, the large- R jets are required to have $p_T > 400$ GeV and $|\eta| < 2.0$.

The missing transverse momentum (with magnitude E_T^{miss}) is calculated as the negative of the vectorial sum of the transverse momenta of all electrons, muons, and jets, as well as calibrated calorimeter energy clusters within $|\eta| < 4.9$ that are not associated with any other objects [45].

The data used were recorded by single-electron and single-muon triggers, which are fully efficient for leptons with $p_T > 25$ GeV. The analysis selects events that contain exactly one reconstructed electron or muon matching a lepton trigger candidate, $E_T^{\text{miss}} > 30$ GeV and no b -tagged small- R jets. The transverse momentum of the neutrino from the leptonically decaying W boson is assumed to be equal to the missing transverse momentum. The momentum of the neutrino in the z -direction, p_z , is obtained by imposing the W boson mass constraint on the lepton and neutrino system, which leads to a quadratic equation. The p_z is defined as either the real component of the complex solution or the smaller in absolute value of the two real solutions.

In order to maximize the sensitivity to resonances with different masses, three different optimized sets of selection criteria are used to classify the events according to the p_T of the leptonically decaying W candidate ($p_T^{\ell\nu}$) and hadronically decaying W/Z candidate (p_T^{jj} or p_T^J), namely the “low- p_T resolved region” (LRR), “high- p_T resolved region” (HRR) and “merged region” (MR), where the highly boosted W/Z decay products are observed as a single merged jet in the final state. To ensure the orthogonality of the signal regions, events are assigned exclusively to the first region for which the criteria are fulfilled, applying sequentially the MR, HRR, and LRR event selection. The hadronically decaying W/Z candidate is formed by combining the two small- R jets with highest p_T in the resolved regions and its invariant mass m_{jj} is required to be between 65 and 105 GeV. In the LRR (HRR), the event is required to have $p_T^{\ell\nu} > 100$ (300) GeV, $p_T^{jj} > 100$ (300) GeV and $\Delta\phi(j, E_T^{\text{miss}}) > 1$, where $\Delta\phi(j, E_T^{\text{miss}})$ is the azimuthal angle between the leading jet and the missing transverse momentum. The HRR additionally requires the two leading jets to have $p_T > 80$ GeV. In the MR, the large- R jet with the highest p_T is selected as the hadronically decaying W/Z candidate and $p_T^{\ell\nu} > 400$ GeV is also imposed. The jet mass of the selected large- R jet (m_J) is required to be consistent with a W/Z boson mass ($65 < m_J < 105$ GeV) and the azimuthal angle between the jet and the missing transverse momentum, $\Delta\phi(J, E_T^{\text{miss}})$, is required to satisfy $\Delta\phi(J, E_T^{\text{miss}}) > 1$. The signal acceptance times efficiency after all selection requirements increases from about 5 % at $m_{W'} = 300$ GeV to a plateau of around 25 % for $m_{W'} > 500$ GeV for $W' \rightarrow WZ \rightarrow \ell\nu q\bar{q}$ with $\ell = e, \mu, \tau$.

5 Background estimation

The reconstructed WW/WZ mass, $m_{\ell\nu jj}$ ($m_{\ell\nu J}$), defined as the invariant mass of the $\ell\nu jj$ ($\ell\nu J$) system, is used to distinguish the signal from the background. The background distributions from W/Z + jets where W (Z) decays leptonically to $\ell\nu$ ($\ell\ell$) considering the three lepton flavors, $t\bar{t}$, single top-quark and diboson processes are modelled using simulated events. The background shape from multijet production is obtained from an independent data sample that satisfies the signal selection criteria except for the lepton requirement: the electrons are required to satisfy a looser identification criterion (“medium” in Ref. [37]) but not meet the “tight” selection criteria; the selected muons are required to satisfy all the selection criteria after inverting the transverse impact parameter significance cut. The contribution from other processes is subtracted from data in the extraction of the multijet background shape.

The background contributions from $t\bar{t}$, single top-quark and diboson production are normalized to the number of

background events predicted by simulation. The $p_T(W)$ distribution in the $W + \text{jets}$ simulated sample is corrected by comparing it to data in the LRR sidebands defined as $40 < m_{jj} < 65$ or $105 < m_{jj} < 200$ GeV. The normalizations of the $W/Z + \text{jets}$ and multijet background contributions are derived in a control data sample which is obtained by requiring the mass of the hadronic W/Z candidate to be within the $m_J(m_{jj})$ sidebands. They are determined from binned minimum χ^2 fits to the E_T^{miss} distributions in the control data samples corresponding to each signal region and channel separately. The fitted parameters are the normalizations of these two processes. The difference of the $W/Z + \text{jets}$ normalization from the expected background from simulation ranges between 1 and 18 %.

The multijet background templates were validated in the electron channel using samples enriched in multijet events, obtained by inverting the E_T^{miss} requirement. The description of the $t\bar{t}$ background in simulation was validated in a sample dominated by top-pair events by requiring at least one b -tagged small- R jet. Good agreement within uncertainties is observed between data and expectation in these validation regions.

6 Systematic uncertainties

The main systematic uncertainty on the background estimation is the uncertainty on the normalization of $W/Z + \text{jets}$ background obtained from the fit described above. This uncertainty is 3–4 % in the LRR and HRR, and 13–19 % in the MR. An uncertainty on the shape of the $W/Z + \text{jets}$ background is obtained in the LRR by comparing data and simulation in the m_{jj} sidebands, leading to an approximately 5 % uncertainty for $m_{\ell\nu jj} < 600$ GeV. Due to the low numbers of data events in the sidebands for the HRR and MR, the $W + \text{jets}$ shape uncertainty in these regions is evaluated by comparing a sample of simulated events from SHERPA with a sample of simulated events from ALPGEN [46] interfaced to PYTHIA6. The uncertainty in the shape of the $t\bar{t}$ mass distribution is estimated by comparing a sample from MC@NLO interfaced to HERWIG with a sample from POWHEG [47–49] interfaced to PYTHIA6. The uncertainty on the shape of the multijet background is evaluated by using alternative templates obtained by removing the calorimeter-based lepton isolation cuts. For the remaining background processes, detector-related uncertainties from the small- R jet energy scale and resolution, large- R jet energy and mass scale, lepton reconstruction and identification efficiencies, lepton momentum scales and resolutions, and missing transverse momentum were considered when evaluating possible systematic effects on the shape or normalization of the background estimation and are found to have a minor impact. The large- R jet energy and mass scale uncertainties are evaluated

by comparing the ratio of calorimeter-based to track-based measurements in dijet data and simulation, and are validated by in-situ data of high- p_T W production in association with jets.

The dominant uncertainty on the signal arises from initial- and final-state radiation modelling in PYTHIA and is <12 % (6 %) for G^* (W'). Uncertainties due to the choice of PDFs are below 1 %.

The uncertainty on the integrated luminosity is ± 2.8 %. It is determined, following the same methodology as that detailed in Ref. [50], from a calibration of the luminosity scale derived from beam-separation scans performed in November 2012.

7 Results and interpretation

Table 1 shows the number of events predicted and observed in each signal region. The reconstructed $m_{\ell\nu jj}$ ($m_{\ell\nu J}$) distributions for data and predicted background events as well as selected benchmark signal models in the three signal regions are shown in Fig. 1 for the combined electron and muon channels. Good agreement is observed between the data and the background prediction. In the absence of a significant excess, the result is interpreted as 95 % confidence level (CL) upper limits on the production cross section times branching ratio for the G^* and W' models. These upper limits are determined with the CL_s modified frequentist formalism [51] with a profile-likelihood test statistic [52]. The test statistic is evaluated with a maximum-likelihood fit of signal models and background predictions to the reconstructed $m_{\ell\nu jj}$ ($m_{\ell\nu J}$) spectra. Systematic uncertainties are taken into account as nuisance parameters with Gaussian sampling distributions. For each source of systematic uncertainty, the

Table 1 Event yields in signal regions for data, predicted background contributions, and G^* and W' signals. Errors are shown before the fit to the data. The errors on the total background and total signal correspond to the full statistical and systematic uncertainty, while the errors on each background component include the full systematic uncertainty only. The G^* and W' signal hypotheses correspond to resonance masses of 400, 800 and 1200 GeV for the LRR, HRR, and MR selections, respectively

Sample	LRR	HRR	MR
$W/Z + \text{jets}$	104800 ± 1600	415 ± 10	180 ± 20
$t\bar{t} + \text{single top}$	37700 ± 1600	271 ± 13	42 ± 7
Multijet	13500 ± 500	84 ± 9	29.3 ± 2.9
Diboson	5500 ± 270	96 ± 6	43 ± 7
Total	161500 ± 2300	870 ± 40	295 ± 22
Data	157837	801	323
G^* signal	7000 ± 500	36 ± 6	5.5 ± 2.3
W' signal	6800 ± 600	318 ± 21	70 ± 4

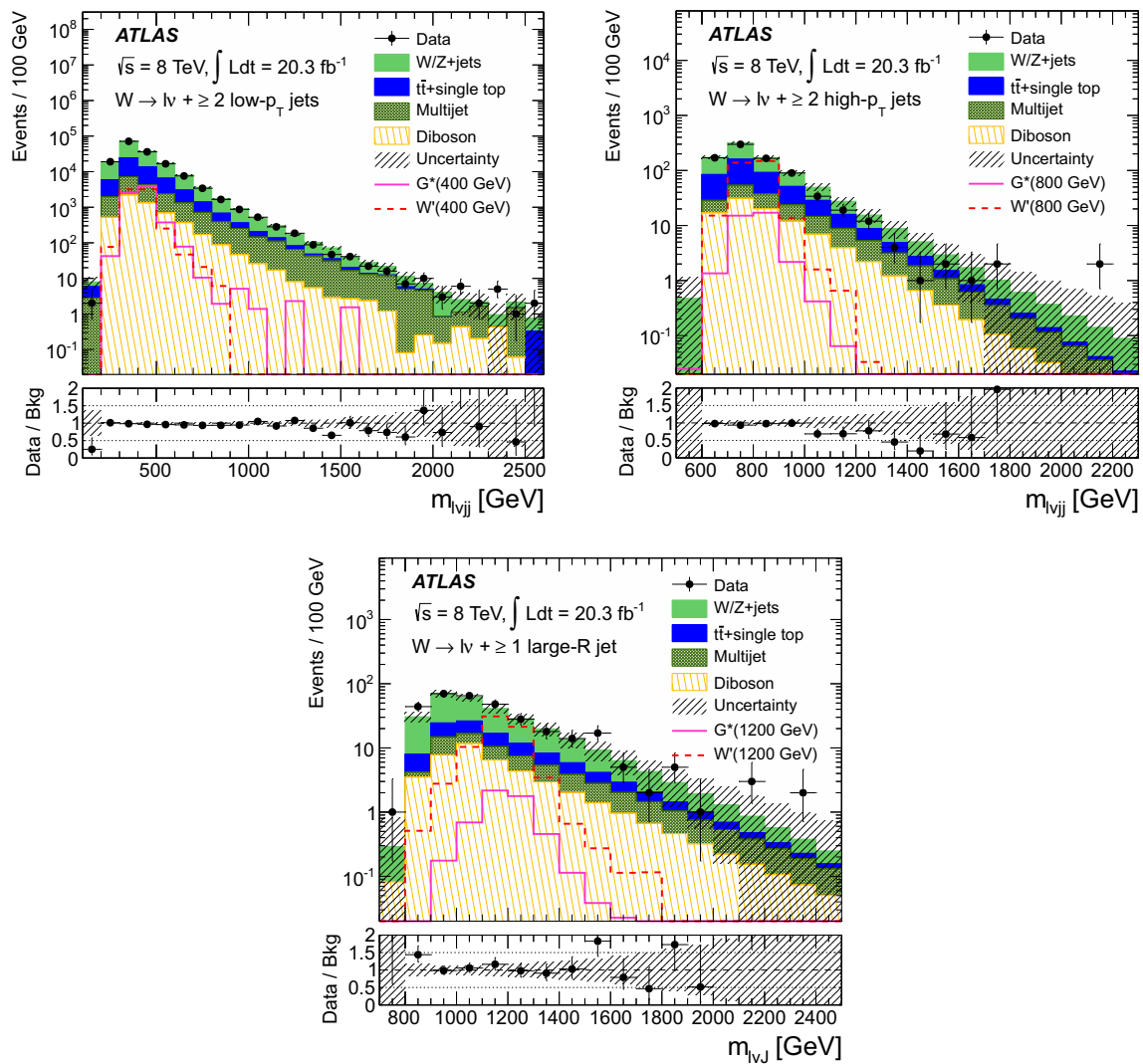


Fig. 1 Reconstructed mass distributions in data and the predicted backgrounds in the three kinematic regions referred to in the text as the low- p_T resolved region (*top left*), high- p_T resolved region (*top right*) and merged region (*bottom*). G^* and W' signal hypotheses of masses 400,

800 and 1200 GeV are also shown. The band denotes the statistical and systematic uncertainty on the background before the fit to the data. The *lower panels* show the ratio of data to the SM background estimate

correlations across bins and between different kinematic regions, as well as those between signal and background, are taken into account. The likelihood fit is performed for signal pole masses between 300 and 800 GeV for the LRR, 600–1000 GeV for the HRR and 800–2000 GeV for the MR. Overlapping regions are fit simultaneously. Figure 2 shows 95 % CL upper limits on the production cross section multiplied by the branching fraction into WW (WZ) for the bulk RS G^* (EGM W') as a function of the resonance pole mass. The theoretical predictions for the EGM W' with a scale factor $c = 1$ and the bulk RS G^* with coupling constant $k/\bar{M}_{\text{Pl}} = 1$, shown in the figure, allow observed lower mass limits of 1490 GeV for the W' and 700 GeV for the G^* to be extracted.

8 Summary

A search for WW and WZ resonances decaying to a lepton, neutrino and jets is presented in this paper. The search is performed using an integrated luminosity of 20.3 fb^{-1} of pp collisions at $\sqrt{s} = 8 \text{ TeV}$ collected by the ATLAS detector at the LHC. A set of event selections for bulk RS G^* and EGM W' boson signal is derived using simulated events and applied to the data. No evidence for resonant diboson production is observed and 95 % CL upper limits on the production cross section times branching fraction of G^* and W' are determined. Resonance masses below 700 GeV are excluded for the spin-2 RS graviton G^* and masses below 1490 GeV are excluded for the spin-1 EGM W' boson at

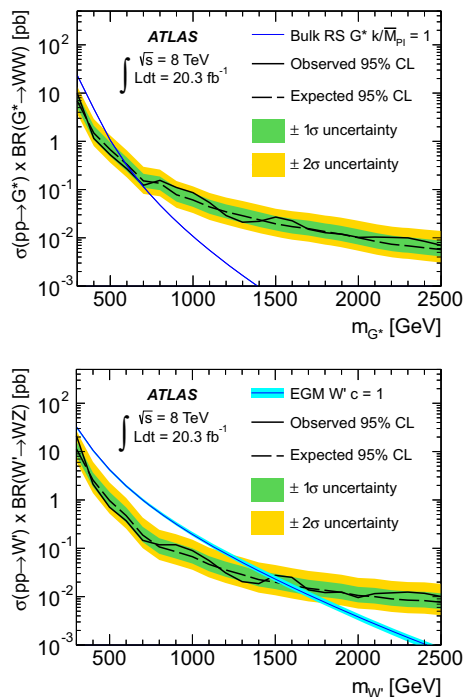


Fig. 2 Observed and expected 95 % CL *upper limits* on the cross section times branching fraction as a function of the resonance pole mass for the G^* (*top*) and EGM W' (*bottom*). The LO (NNLO) theoretical cross section for the G^* (EGM W') production is also shown. The *inner* and *outer* bands around the expected limits represent $\pm 1\sigma$ and $\pm 2\sigma$ variations respectively. The band around the W' cross section corresponds to the NNLO theory uncertainty

95 % CL. The analysis also sets the most stringent limits to date on the production cross section for W' -like resonances decaying to WZ with masses around 2 TeV, where $\sigma(pp \rightarrow W') \times BR(W' \rightarrow WZ)$ values of 9.6 fb are excluded. The results represent a significant improvement over previously reported limits [11] in the same final state due to an increased data set size and the development of new techniques to analyse highly boosted bosons that decay hadronically.

Acknowledgments We thank CERN for the very successful operation of the LHC, as well as the support staff from our institutions without whom ATLAS could not be operated efficiently. We acknowledge the support of ANPCyT, Argentina; YerPhI, Armenia; ARC, Australia; BMWFW and FWF, Austria; ANAS, Azerbaijan; SSTC, Belarus; CNPq and FAPESP, Brazil; NSERC, NRC and CFI, Canada; CERN; CONICYT, Chile; CAS, MOST and NSFC, China; COLCIENCIAS, Colombia; MSMT CR, MPO CR and VSC CR, Czech Republic; DNRF, DNSRC and Lundbeck Foundation, Denmark; EPLANET, ERC and NSRF, European Union; IN2P3-CNRS, CEA-DSM/IRFU, France; GNSF, Georgia; BMBF, DFG, HGF, MPG and AvH Foundation, Germany; GSRT and NSRF, Greece; RGC, Hong Kong SAR, China; ISF, MINERVA, GIF, I-CORE and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; FOM and NWO, The Netherlands; BRF and RCN, Norway; MNiSW and NCN, Poland; GRICES and FCT, Portugal; MNE/IFA, Romania; MES of Russia and NRC KI, Russian Federation; JINR; MSTB, Serbia; MSSR, Slo-

vakia; ARRS and MIZŠ, Slovenia; DST/NRF, South Africa; MINECO, Spain; SRC and Wallenberg Foundation, Sweden; SER, SNSF and Cantons of Bern and Geneva, Switzerland; NSC, Taiwan; TAEK, Turkey; STFC, the Royal Society and Leverhulme Trust, United Kingdom; DOE and NSF, United States of America. The crucial computing support from all WLCG partners is acknowledged gratefully, in particular from CERN and the ATLAS Tier-1 facilities at TRIUMF (Canada), NDGF (Denmark, Norway, Sweden), CC-IN2P3 (France), KIT/GridKA (Germany), INFN-CNAF (Italy), NL-T1 (The Netherlands), PIC (Spain), ASGC (Taiwan), RAL (UK) and BNL (USA) and in the Tier-2 facilities worldwide.

Open Access This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. Funded by SCOAP³.

References

1. E. Eichten, K. Lane, Low-scale technicolor at the Tevatron and LHC. *Phys. Lett. B* **669**, 235 (2008). [arXiv:0706.2339](https://arxiv.org/abs/0706.2339) [hep-ph]
2. S. Catterall, L. Del Debbio, J. Giedt, L. Keegan, Monte Carlo renormalization group minimal walking technicolor. *Phys. Rev. D* **85**, 094501 (2012). [arXiv:1108.3794](https://arxiv.org/abs/1108.3794) [hep-ph]
3. J.R. Andersen et al., Discovering technicolor. *Eur. Phys. J. Plus* **126**, 81 (2011). [arXiv:1104.1255](https://arxiv.org/abs/1104.1255) [hep-ph]
4. L. Randall, R. Sundrum, Large mass hierarchy from a small extra dimension. *Phys. Rev. Lett.* **83**, 3370 (1999). [arXiv:hep-ph/9905221](https://arxiv.org/abs/hep-ph/9905221)
5. L. Randall, R. Sundrum, An alternative to compactification. *Phys. Rev. Lett.* **83**, 4690 (1999). [arXiv:hep-th/9906064](https://arxiv.org/abs/hep-th/9906064)
6. H. Davoudiasl, J.L. Hewett, T.G. Rizzo, Experimental probes of localized gravity: on and off the wall. *Phys. Rev. D* **63**, 075004 (2001). [arXiv:hep-ph/0006041](https://arxiv.org/abs/hep-ph/0006041)
7. G. Altarelli, B. Mele, M. Ruiz-Altaba, Searching for new heavy vector bosons in $p\bar{p}$ colliders. *Z. Phys. C* **45**, 109 (1989). [erratum-ibid C **47**, 676 (1990)]
8. K. Agashe, H. Davoudiasl, G. Perez, A. Soni, Warped gravitons at the CERN LHC and beyond. *Phys. Rev. D* **76**, 036006 (2007). [arXiv:hep-ph/0701186](https://arxiv.org/abs/hep-ph/0701186)
9. CMS Collaboration, Search for massive resonances in dijet systems containing jets tagged as W or Z boson decays in pp collisions at $\sqrt{s} = 8$ TeV. *J. High Energy Phys.* **08**, 173 (2014). [arXiv:1405.1994](https://arxiv.org/abs/1405.1994) [hep-ex]
10. CMS Collaboration, Search for massive resonances decaying into pairs of boosted bosons in semi-leptonic final states at $\sqrt{s} = 8$ TeV. *J. High Energy Phys.* **08**, 174 (2014). [arXiv:1405.3447](https://arxiv.org/abs/1405.3447) [hep-ex]
11. ATLAS Collaboration, Search for resonant diboson production in the $WW/WZ \rightarrow \ell\nu jj$ decay channels with the ATLAS detector at $\sqrt{s} = 7$ TeV. *Phys. Rev. D* **87**, 112006 (2013). [arXiv:1305.0125](https://arxiv.org/abs/1305.0125) [hep-ex]
12. ATLAS Collaboration, Search for WZ resonances in the fully leptonic channel using pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector. *Phys. Lett. B* **737**, 223 (2014). [arXiv:1406.4456](https://arxiv.org/abs/1406.4456) [hep-ex]
13. ATLAS Collaboration, Search for resonant diboson production in the $\ell\ell q\bar{q}$ final state in pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector. *Eur. Phys. J. C* **75**, 69 (2015). [arXiv:1409.6190](https://arxiv.org/abs/1409.6190) [hep-ex]
14. ATLAS Collaboration, The ATLAS experiment at the CERN large hadron collider. *JINST* **3**, S08003 (2008)
15. A. Belyaev, N.D. Christensen, A. Pukhov, CalcHEP 3.4 for collider physics within and beyond the standard model. *Comput. Phys.*

- Commun. **184**, 1729 (2013). [CalcHEP 3.4.3; with the overestimate of the Randall–Sundrum graviton production cross section by a factor of four corrected as reported in <http://cp3-origins.dk/research/units/ed-tools> (2013)]. [arXiv:1207.6082](#) [hep-ph]
16. T. Sjöstrand, S. Mrenna, P. Skands, A brief introduction to PYTHIA 8.1. Comput. Phys. Commun. **178**, 852 (2008). [arXiv:0710.3820](#) [hep-ph]
 17. J. Pumplin et al., New generation of parton distributions with uncertainties from global QCD analysis. J. High Energy Phys. **07**, 012 (2002). [arXiv:hep-ph/0201195](#)
 18. A.D. Martin, W.J. Stirling, R.S. Thorne, G. Watt, Parton distributions for the LHC. Eur. Phys. J. C **63**, 189 (2009). [arXiv:0901.0002](#) [hep-ph]
 19. R. Hamberg, W.L. van Neerven, T. Matsuura, A complete calculation of the order α_s^2 correction to the Drell–Yan K -factor. Nucl. Phys. B **359**, 343 (1991)
 20. T. Gleisberg et al., Event generation with SHERPA 1.1. J. High Energy Phys. **02**, 007 (2009). [arXiv:0811.4622](#) [hep-ph]
 21. H.-L. Lai et al., New parton distributions for collider physics. Phys. Rev. D **82**, 074024 (2010). [arXiv:1007.2241](#) [hep-ph]
 22. S. Frixione, B.R. Webber, Matching NLO QCD computations and parton shower simulations. J. High Energy Phys. **06**, 029 (2002). [arXiv:hep-ph/0204244](#)
 23. G. Corcella et al., HERWIG 6: an event generator for hadron emission reactions with interfering gluons (including supersymmetric processes). J. High Energy Phys. **01**, 010 (2001). [arXiv:hep-ph/0011363](#)
 24. J.M. Butterworth, J.R. Forshaw, M.H. Seymour, Multiparton interactions in photoproduction at HERA. Z. Phys. C **72**, 637 (1996). [arXiv:hep-ph/9601371](#)
 25. M. Cacciari et al., Top-pair production at hadron colliders with next-to-next-to-leading logarithmic soft-gluon resummation. Phys. Lett. B **710**, 612 (2012). [arXiv:1111.5869](#) [hep-ph]
 26. M. Beneke, P. Falgari, S. Klein, C. Schwinn, Hadronic top-quark pair production with NNLL threshold resummation. Nucl. Phys. B **855**, 695 (2012). [arXiv:1109.1536](#) [hep-ph]
 27. P. Bärnreuther, M. Czakon, A. Mitov, Percent-level-precision physics at the Tevatron: next-to-next-to-leading order QCD corrections to $q\bar{q} \rightarrow t\bar{t} + X$. Phys. Rev. Lett. **109**, 132001 (2012). [arXiv:1204.5201](#) [hep-ph]
 28. M. Czakon, A. Mitov, NNLO corrections to top-pair production at hadron colliders: the all-fermionic scattering channels. J. High Energy Phys. **12**, 054 (2012). [arXiv:1207.0236](#) [hep-ph]
 29. M. Czakon, A. Mitov, NNLO corrections to top pair production at hadron colliders: the quark–gluon reaction. J. High Energy Phys. **01**, 080 (2013). [arXiv:1210.6832](#) [hep-ph]
 30. M. Czakon, P. Fiedler, A. Mitov, Total top-quark pair-production cross section at hadron colliders through $\mathcal{O}(\alpha_s^4)$. Phys. Rev. Lett. **110**, 252004 (2013). [arXiv:1303.6254](#) [hep-ph]
 31. M. Czakon, A. Mitov, Top++: a program for the calculation of the top-pair cross-section at hadron colliders. Comput. Phys. Commun. **185**, 2930 (2014). [arXiv:1112.5675](#) [hep-ph]
 32. B.P. Kersevan, E. Richter-Was, The Monte Carlo event generator AcerMC versions 2.0 to 3.8 with interfaces to PYTHIA 6.4, HERWIG 6.5 and ARIADNE 4.1. Comput. Phys. Commun. **184**, 919 (2013). [arXiv:hep-ph/0405247](#)
 33. T. Sjöstrand, S. Mrenna, P. Skands, PYTHIA 6.4 physics and manual. J. High Energy Phys. **05**, 026 (2006). [arXiv:hep-ph/0603175](#)
 34. S. Agostinelli et al., GEANT4: a simulation toolkit. Nucl. Instrum. Methods A **506**, 250 (2003)
 35. ATLAS Collaboration, The ATLAS simulation infrastructure. Eur. Phys. J. C **70**, 823 (2010). [arXiv:1005.4568](#) [physics.ins-det]
 36. ATLAS Collaboration, The simulation principle and performance of the ATLAS fast calorimeter simulation FastCaloSim. ATL-PHYS-PUB-2010-013 (2010). <http://cdsweb.cern.ch/record/1300517>. Accessed 7 May 2015
 37. ATLAS Collaboration, Electron performance measurements with the ATLAS detector using the 2010 LHC proton–proton collision data. Eur. Phys. J. C **72**, 1909 (2012). [arXiv:1110.3174](#) [hep-ex]
 38. ATLAS Collaboration, Measurement of the muon reconstruction performance of the ATLAS detector using 2011 and 2012 LHC proton–proton collision data. Eur. Phys. J. C **74**, 3130 (2014). [arXiv:1407.3935](#) [hep-ex]
 39. M. Cacciari, G.P. Salam, G. Soyez, The anti- k_t jet clustering algorithm. J. High Energy Phys. **04**, 063 (2008). [arXiv:0802.1189](#) [hep-ph]
 40. ATLAS Collaboration, Jet energy measurement with the ATLAS detector in proton–proton collisions at $\sqrt{s} = 7$ TeV. Eur. Phys. J. C **73**, 2304 (2013). [arXiv:1112.6426](#) [hep-ex]
 41. ATLAS Collaboration, Calibration of the performance of b -tagging for c and light-flavour jets in the 2012 ATLAS data. ATLAS-CONF-2014-046 (2014). <http://cdsweb.cern.ch/record/1741020>. Accessed 7 May 2015
 42. Y.L. Dokshitzer, G.D. Leder, S. Moretti, B.R. Webber, Better jet clustering algorithms. J. High Energy Phys. **08**, 001 (1997). [arXiv:hep-ph/9707323](#)
 43. J.M. Butterworth, A.R. Davison, M. Rubin, G.P. Salam, Jet substructure as a new Higgs-search channel at the large hadron collider. Phys. Rev. Lett. **100**, 242001 (2008). [arXiv:0802.2470](#) [hep-ph]
 44. ATLAS Collaboration, Performance of boosted W boson identification with the ATLAS detector. ATL-PHYS-PUB-2014-004 (2014). <http://cdsweb.cern.ch/record/1690048>. Accessed 7 May 2015
 45. ATLAS Collaboration, Performance of missing transverse momentum reconstruction in proton–proton collisions at $\sqrt{s} = 7$ TeV with ATLAS. Eur. Phys. J. C **72**, 1844 (2012). [arXiv:1108.5602](#) [hep-ex]
 46. M.L. Mangano et al., ALPGEN, a generator for hard multiparton processes in hadronic collisions. J. High Energy Phys. **07**, 001 (2003). [arXiv:hep-ph/0206293](#)
 47. P. Nason, A new method for combining NLO QCD with shower Monte Carlo algorithms. J. High Energy Phys. **11**, 040 (2004). [arXiv:hep-ph/0409146](#)
 48. S. Frixione, P. Nason, C. Oleari, Matching NLO QCD computations with parton shower simulations: the POWHEG method. J. High Energy Phys. **11**, 070 (2007). [arXiv:0709.2092](#) [hep-ph]
 49. S. Alioli, P. Nason, C. Oleari, E. Re, A general framework for implementing NLO calculations in shower Monte Carlo programs: the POWHEG BOX. J. High Energy Phys. **06**, 043 (2010). [arXiv:1002.2581](#) [hep-ph]
 50. ATLAS Collaboration, Improved luminosity determination in pp collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector at the LHC. Eur. Phys. J. C **73**, 2518 (2013). [arXiv:1302.4393](#) [hep-ex]
 51. A.L. Read, Presentation of search results: the CL_s technique. J. Phys. G **28**, 2693 (2002)
 52. G. Cowan, K. Cranmer, E. Gross, O. Vitells, Asymptotic formulae for likelihood-based tests of new physics. Eur. Phys. J. C **71**, 1554 (2011). [arXiv:1007.1727](#) [physics.data-an]

ATLAS Collaboration

G. Aad⁸⁵, B. Abbott¹¹³, J. Abdallah¹⁵², S. Abdel Khalek¹¹⁷, O. Abidinov¹¹, R. Aben¹⁰⁷, B. Abi¹¹⁴, M. Abolins⁹⁰, O. S. AbouZeid¹⁵⁹, H. Abramowicz¹⁵⁴, H. Abreu¹⁵³, R. Abreu³⁰, Y. Abulaiti^{147a,147b}, B. S. Acharya^{165a,165b}, L. Adamczyk^{38a}, D. L. Adams²⁵, J. Adelman¹⁰⁸, S. Adomeit¹⁰⁰, T. Adye¹³¹, T. Agatonovic-Jovin¹³, J. A. Aguilar-Saavedra^{126a,126f}, M. Agustoni¹⁷, S. P. Ahlen²², F. Ahmadov^{65,b}, G. Aielli^{134a,134b}, H. Akerstedt^{147a,147b}, T. P. A. Åkesson⁸¹, G. Akimoto¹⁵⁶, A. V. Akimov⁹⁶, G. L. Alberghi^{20a,20b}, J. Albert¹⁷⁰, S. Albrand⁵⁵, M. J. Alconada Verzini⁷¹, M. Aleksa³⁰, I. N. Aleksandrov⁶⁵, C. Alexa^{26a}, G. Alexander¹⁵⁴, G. Alexandre⁴⁹, T. Alexopoulos¹⁰, M. Alhoob¹¹³, G. Alimonti^{91a}, L. Alio⁸⁵, J. Alison³¹, B. M. M. Allbrooke¹⁸, L. J. Allison⁷², P. P. Allport⁷⁴, A. Aloisio^{104a,104b}, A. Alonso³⁶, F. Alonso⁷¹, C. Alpigiani⁷⁶, A. Altheimer³⁵, B. Alvarez Gonzalez⁹⁰, M. G. Alviggi^{104a,104b}, K. Amako⁶⁶, Y. Amaral Coutinho^{24a}, C. Amelung²³, D. Amidei⁸⁹, S. P. Amor Dos Santos^{126a,126c}, A. Amorim^{126a,126b}, S. Amoroso⁴⁸, N. Amram¹⁵⁴, G. Amundsen²³, C. Anastopoulos¹⁴⁰, L. S. Ancu⁴⁹, N. Andari³⁰, T. Andeen³⁵, C. F. Anders^{58b}, G. Anders³⁰, K. J. Anderson³¹, A. Andreazza^{91a,91b}, V. Andrei^{58a}, X. S. Anduaga⁷¹, S. Angelidakis⁹, I. Angelozzi¹⁰⁷, P. Anger⁴⁴, A. Angerami³⁵, F. Anghinolfi³⁰, A. V. Anisenkov^{109,c}, N. Anjos¹², A. Annovi^{124a,124b}, M. Antonelli⁴⁷, A. Antonov⁹⁸, J. Antos^{145b}, F. Anulli^{133a}, M. Aoki⁶⁶, L. Aperio Bella¹⁸, G. Arabidze⁹⁰, Y. Arai⁶⁶, J. P. Araque^{126a}, A. T. H. Arce⁴⁵, F. A. Arduh⁷¹, J-F. Arguin⁹⁵, S. Argyropoulos⁴², M. Arik^{19a}, A. J. Armbruster³⁰, O. Arnaez³⁰, V. Arnal⁸², H. Arnold⁴⁸, M. Arratia²⁸, O. Arslan²¹, A. Artamonov⁹⁷, G. Artoni²³, S. Asai¹⁵⁶, N. Asbah⁴², A. Ashkenazi¹⁵⁴, B. Åsman^{147a,147b}, L. Asquith¹⁵⁰, K. Assamagan²⁵, R. Astalos^{145a}, M. Atkinson¹⁶⁶, N. B. Atlay¹⁴², B. Auerbach⁶, K. Augsten¹²⁸, M. Auresseau^{146b}, G. Avolio³⁰, B. Axen¹⁵, M. K. Ayoub¹¹⁷, G. Azuelos^{95,d}, M. A. Baak³⁰, A. E. Baas^{58a}, C. Bacci^{135a,135b}, H. Bachacou¹³⁷, K. Bachas¹⁵⁵, M. Backes³⁰, M. Backhaus³⁰, P. Bagiacchi^{133a,133b}, P. Bagnaia^{133a,133b}, Y. Bai^{33a}, T. Bain³⁵, J. T. Baines¹³¹, O. K. Baker¹⁷⁷, P. Balek¹²⁹, T. Balestri¹⁴⁹, F. Balli⁸⁴, E. Banas³⁹, Sw. Banerjee¹⁷⁴, A. A. E. Bannoura¹⁷⁶, H. S. Bansil¹⁸, L. Barak¹⁷³, S. P. Baranov⁹⁶, E. L. Barberio⁸⁸, D. Barberis^{50a,50b}, M. Barbero⁸⁵, T. Barillari¹⁰¹, M. Barisonzi^{165a,165b}, T. Barklow¹⁴⁴, N. Barlow²⁸, S. L. Barnes⁸⁴, B. M. Barnett¹³¹, R. M. Barnett¹⁵, Z. Barnovska⁵, A. Baroncelli^{135a}, G. Barone⁴⁹, A. J. Barr¹²⁰, F. Barreiro⁸², J. Barreiro Guimarães da Costa⁵⁷, R. Bartoldus¹⁴⁴, A. E. Barton⁷², P. Bartos^{145a}, A. Bassalat¹¹⁷, A. Basye¹⁶⁶, R. L. Bates⁵³, S. J. Batista¹⁵⁹, J. R. Batley²⁸, M. Battaglia¹³⁸, M. Bauce^{133a,133b}, F. Bauer¹³⁷, H. S. Bawa^{144,e}, J. B. Beacham¹¹¹, M. D. Beattie⁷², T. Beau⁸⁰, P. H. Beauchemin¹⁶², R. Beccherle^{124a,124b}, P. Bechtel²¹, H. P. Beck^{17,f}, K. Becker¹²⁰, S. Becker¹⁰⁰, M. Beckingham¹⁷¹, C. Becot¹¹⁷, A. J. Beddall^{19c}, A. Beddall^{19c}, V. A. Bednyakov⁶⁵, C. P. Bee¹⁴⁹, L. J. Beemster¹⁰⁷, T. A. Beermann¹⁷⁶, M. Begel²⁵, J. K. Behr¹²⁰, C. Belanger-Champagne⁸⁷, P. J. Bell⁴⁹, W. H. Bell⁴⁹, G. Bella¹⁵⁴, L. Bellagamba^{20a}, A. Bellerive²⁹, M. Bellomo⁸⁶, K. Belotskiy⁹⁸, O. Beltramello³⁰, O. Benary¹⁵⁴, D. Benchechroun^{136a}, M. Bender¹⁰⁰, K. Bendtz^{147a,147b}, N. Benekos¹⁰, Y. Benhammou¹⁵⁴, E. Benhar Nocchioli⁴⁹, J. A. Benitez Garcia^{160b}, D. P. Benjamin⁴⁵, J. R. Bensinger²³, S. Bentvelsen¹⁰⁷, L. Beresford¹²⁰, M. Beretta⁴⁷, D. Berge¹⁰⁷, E. Bergeas Kuutmann¹⁶⁷, N. Berger⁵, F. Berghaus¹⁷⁰, J. Beringer¹⁵, C. Bernard²², N. R. Bernard⁸⁶, C. Bernius¹¹⁰, F. U. Bernlochner²¹, T. Berry⁷⁷, P. Berta¹²⁹, C. Bertella⁸³, G. Bertoli^{147a,147b}, F. Bertolucci^{124a,124b}, C. Bertsche¹¹³, D. Bertsche¹¹³, M. I. Besana^{91a}, G. J. Besjes¹⁰⁶, O. Bessidskaia Bylund^{147a,147b}, M. Bessner⁴², N. Besson¹³⁷, C. Betancourt⁴⁸, S. Bethke¹⁰¹, A. J. Bevan⁷⁶, W. Bhimji⁴⁶, R. M. Bianchi¹²⁵, L. Bianchini²³, M. Bianco³⁰, O. Biebel¹⁰⁰, S. P. Bieniek⁷⁸, M. Biglietti^{135a}, J. Bilbao De Mendizabal⁴⁹, H. Bilokon⁴⁷, M. Bindi⁵⁴, S. Binet¹¹⁷, A. Bingul^{19c}, C. Bini^{133a,133b}, C. W. Black¹⁵¹, J. E. Black¹⁴⁴, K. M. Black²², D. Blackburn¹³⁹, R. E. Blair⁶, J.-B. Blanchard¹³⁷, J.E. Blanco⁷⁷, T. Blazek^{145a}, I. Bloch⁴², C. Blocker²³, W. Blum^{83,*}, U. Blumenschein⁵⁴, G. J. Bobbink¹⁰⁷, V. S. Bobrovnikov^{109,c}, S. S. Bocchetta⁸¹, A. Bocci⁴⁵, C. Bock¹⁰⁰, C. R. Boddy¹²⁰, M. Boehler⁴⁸, J. A. Bogaerts³⁰, A. G. Bogdanchikov¹⁰⁹, C. Bohm^{147a}, V. Boisvert⁷⁷, T. Bold^{38a}, V. Boldea^{26a}, A. S. Boldyrev⁹⁹, M. Bomben⁸⁰, M. Bona⁷⁶, M. Boonekamp¹³⁷, A. Borisov¹³⁰, G. Borissov⁷², S. Borroni⁴², J. Bortfeldt¹⁰⁰, V. Bortolotto^{60a}, K. Bos¹⁰⁷, D. Boscherini^{20a}, M. Bosman¹², J. Boudreau¹²⁵, J. Bouffard², E. V. Bouhova-Thacker⁷², D. Boumediene³⁴, C. Bourdarios¹¹⁷, N. Bousson¹¹⁴, S. Boutouil^{136d}, A. Boveia³⁰, J. Boyd³⁰, I. R. Boyko⁶⁵, I. Bozic¹³, J. Bracinik¹⁸, A. Brandt⁸, G. Brandt¹⁵, O. Brandt^{58a}, U. Bratzler¹⁵⁷, B. Brau⁸⁶, J. E. Brau¹¹⁶, H. M. Braun^{176,*}, S. F. Brazzale^{165a,165c}, K. Brendlinger¹²², A. J. Brennan⁸⁸, L. Brenner¹⁰⁷, R. Brenner¹⁶⁷, S. Bressler¹⁷³, K. Bristow^{146c}, T. M. Bristow⁴⁶, D. Britton⁵³, D. Britzger⁴², F. M. Brochu²⁸, I. Brock²¹, R. Brock⁹⁰, J. Bronner¹⁰¹, G. Brooijmans³⁵, T. Brooks⁷⁷, W. K. Brooks^{32b}, J. Brosamer¹⁵, E. Brost¹¹⁶, J. Brown⁵⁵, P. A. Bruckman de Renstrom³⁹, D. Bruncko^{145b}, R. Bruneliere⁴⁸, A. Bruni^{20a}, G. Bruni^{20a}, M. Bruschi^{20a}, L. Bryngemark⁸¹, T. Buanes¹⁴, Q. Buat¹⁴³, F. Bucci⁴⁹, P. Buchholz¹⁴², A. G. Buckley⁵³, S. I. Buda^{26a}, I. A. Budagov⁶⁵, F. Buehrer⁴⁸, L. Bugge¹¹⁹, M. K. Bugge¹¹⁹, O. Bulekov⁹⁸, H. Burckhart³⁰, S. Burdin⁷⁴, B. Burghgrave¹⁰⁸, S. Burke¹³¹, I. Burmeister⁴³, E. Busato³⁴, D. Büscher⁴⁸, V. Büscher⁸³, P. Bussey⁵³, C. P. Buszello¹⁶⁷, J. M. Butler²², A. I. Butt³, C. M. Buttar⁵³, J. M. Butterworth⁷⁸, P. Butti¹⁰⁷, W. Buttinger²⁵, A. Buzatu⁵³, S. Cabrera Urbán¹⁶⁸, D. Caforio¹²⁸, O. Cakir^{4a}, P. Calafiura¹⁵, A. Calandri¹³⁷, G. Calderini⁸⁰, P. Calfayan¹⁰⁰, L. P. Caloba^{24a}, D. Calvet³⁴, S. Calvet³⁴,

- R. Camacho Toro⁴⁹, S. Camarda⁴², D. Cameron¹¹⁹, L. M. Caminada¹⁵, R. Caminal Armadans¹², S. Campana³⁰, M. Campanelli⁷⁸, A. Campoverde¹⁴⁹, V. Canale^{104a,104b}, A. Canepa^{160a}, M. Cano Bret⁷⁶, J. Cantero⁸², R. Cantrill^{126a}, T. Cao⁴⁰, M. D. M. Capeans Garrido³⁰, I. Caprini^{26a}, M. Caprini^{26a}, M. Capua^{37a,37b}, R. Caputo⁸³, R. Cardarelli^{134a}, T. Carli³⁰, G. Carlino^{104a}, L. Carminati^{91a,91b}, S. Caron¹⁰⁶, E. Carquin^{32a}, G. D. Carrillo-Montoya^{146c}, J. R. Carter²⁸, J. Carvalho^{126a,126c}, D. Casadei⁷⁸, M. P. Casado¹², M. Casolino¹², E. Castaneda-Miranda^{146b}, A. Castelli¹⁰⁷, V. Castillo Gimenez¹⁶⁸, N. F. Castro^{126a,g}, P. Catastini⁵⁷, A. Catinaccio³⁰, J. R. Catmore¹¹⁹, A. Cattai³⁰, G. Cattani^{134a,134b}, J. Caudron⁸³, V. Cavaliere¹⁶⁶, D. Cavalli^{91a}, M. Cavalli-Sforza¹², V. Cavasinni^{124a,124b}, F. Ceradini^{135a,135b}, B. C. Cerio⁴⁵, K. Cerny¹²⁹, A. S. Cerqueira^{24b}, A. Cerri¹⁵⁰, L. Cerrito⁷⁶, F. Cerutti¹⁵, M. Cerv³⁰, A. Cervelli¹⁷, S. A. Cetin^{19b}, A. Chafaq^{136a}, D. Chakraborty¹⁰⁸, I. Chalupkova¹²⁹, P. Chang¹⁶⁶, B. Chapleau⁸⁷, J. D. Chapman²⁸, D. Charfeddine¹¹⁷, D. G. Charlton¹⁸, C. C. Chau¹⁵⁹, C. A. Chavez Barajas¹⁵⁰, S. Cheatham¹⁵³, A. Chegwiddden⁹⁰, S. Chekanov⁶, S. V. Chekulaev^{160a}, G. A. Chelkov^{65,h}, M. A. Chelstowska⁸⁹, C. Chen⁶⁴, H. Chen²⁵, K. Chen¹⁴⁹, L. Chen^{33d,i}, S. Chen^{33c}, X. Chen^{33f}, Y. Chen⁶⁷, H. C. Cheng⁸⁹, Y. Cheng³¹, A. Cheplakov⁶⁵, E. Cheremushkina¹³⁰, R. Cherkaoui El Moursli^{136e}, V. Chernyatin^{25,*}, E. Cheu⁷, L. Chevalier¹³⁷, V. Chiarella⁴⁷, J. T. Childers⁶, A. Chilingarov⁷², G. Chiodini^{73a}, A. S. Chisholm¹⁸, R. T. Chislett⁷⁸, A. Chitan^{26a}, M. V. Chizhov⁶⁵, K. Choi⁶¹, S. Chouridou⁹, B. K. B. Chow¹⁰⁰, D. Chromek-Burckhart³⁰, M. L. Chu¹⁵², J. Chudoba¹²⁷, J. J. Chwastowski³⁹, L. Chytka¹¹⁵, G. Ciapetti^{133a,133b}, A. K. Ciftci^{4a}, D. Cinca⁵³, V. Cindro⁷⁵, A. Cicio¹⁵, Z. H. Citron¹⁷³, M. Ciubancan^{26a}, A. Clark⁴⁹, P. J. Clark⁴⁶, R. N. Clarke¹⁵, W. Cleland¹²⁵, C. Clement^{147a,147b}, Y. Coadou⁸⁵, M. Cobal^{165a,165c}, A. Cocco¹³⁹, J. Cochran⁶⁴, L. Coffey²³, J. G. Cogan¹⁴⁴, B. Cole³⁵, S. Cole¹⁰⁸, A. P. Colijn¹⁰⁷, J. Collot⁵⁵, T. Colombo^{58c}, G. Compostella¹⁰¹, P. Conde Muño^{126a,126b}, E. Coniavitis⁴⁸, S. H. Connell^{146b}, I. A. Connelly⁷⁷, S. M. Consonni^{91a,91b}, V. Consorti⁴⁸, S. Constantinescu^{26a}, C. Conta^{121a,121b}, G. Conti³⁰, F. Conventi^{104a,j}, M. Cooke¹⁵, B. D. Cooper⁷⁸, A. M. Cooper-Sarkar¹²⁰, K. Copic¹⁵, T. Cornelissen¹⁷⁶, M. Corradi^{20a}, F. Corriveau^{87,k}, A. Corso-Radu¹⁶⁴, A. Cortes-Gonzalez¹², G. Cortiana¹⁰¹, G. Costa^{91a}, M. J. Costa¹⁶⁸, D. Costanzo¹⁴⁰, D. Côté⁸, G. Cottin²⁸, G. Cowan⁷⁷, B. E. Cox⁸⁴, K. Cranmer¹¹⁰, G. Cree²⁹, S. Crépe-Renaudin⁵⁵, F. Crescioli⁸⁰, W. A. Cribbs^{147a,147b}, M. Crispin Ortuzar¹²⁰, M. Cristinziani²¹, V. Croft¹⁰⁶, G. Crosetti^{37a,37b}, T. Cuhadar Donszelmann¹⁴⁰, J. Cummings¹⁷⁷, M. Curatolo⁴⁷, C. Cuthbert¹⁵¹, H. Czirr¹⁴², P. Czodrowski³, S. D'Auria⁵³, M. D'Onofrio⁷⁴, M. J. Da Cunha Sargedas De Sousa^{126a,126b}, C. Da Via⁸⁴, W. Dabrowski^{38a}, A. Dafinca¹²⁰, T. Dai⁸⁹, O. Dale¹⁴, F. Dallaire⁹⁵, C. Dallapiccola⁸⁶, M. Dam³⁶, J. R. Dandoy³¹, A. C. Daniels¹⁸, M. Danninger¹⁶⁹, M. Dano Hoffmann¹³⁷, V. Dao⁴⁸, G. Darbo^{50a}, S. Darmora⁸, J. Dassoulas³, A. Dattagupta⁶¹, W. Davey²¹, C. David¹⁷⁰, T. Davidek¹²⁹, E. Davies^{120,l}, M. Davies¹⁵⁴, O. Davignon⁸⁰, P. Davison⁷⁸, Y. Davygora^{58a}, E. Dawe¹⁴³, I. Dawson¹⁴⁰, R. K. Daya-Ishmukhametova⁸⁶, K. De⁸, R. de Asmundis^{104a}, S. De Castro^{20a,20b}, S. De Cecco⁸⁰, N. De Groot¹⁰⁶, P. de Jong¹⁰⁷, H. De la Torre⁸², F. De Lorenzi⁶⁴, L. De Nooij¹⁰⁷, D. De Pedis^{133a}, A. De Salvo^{133a}, U. De Sanctis¹⁵⁰, A. De Santo¹⁵⁰, J. B. De Vivie De Regie¹¹⁷, W. J. Dearnaley⁷², R. Debbé²⁵, C. Debenedetti¹³⁸, D. V. Dedovich⁶⁵, I. Deigaard¹⁰⁷, J. Del Peso⁸², T. Del Prete^{124a,124b}, D. Delgove¹¹⁷, F. Deliot¹³⁷, C. M. Delitzsch⁴⁹, M. Deliyergiyev⁷⁵, A. Dell'Acqua³⁰, L. Dell'Asta²², M. Dell'Orso^{124a,124b}, M. Della Pietra^{104a,j}, D. della Volpe⁴⁹, M. Delmastro⁵, P. A. Delsart⁵⁵, C. Deluca¹⁰⁷, D. A. DeMarco¹⁵⁹, S. Demers¹⁷⁷, M. Demichev⁶⁵, A. Demilly⁸⁰, S. P. Denisov¹³⁰, D. Derendarz³⁹, J. E. Derkaoui^{136d}, F. Derue⁸⁰, P. Dervan⁷⁴, K. Desch²¹, C. Deterre⁴², P. O. Deviveiros³⁰, A. Dewhurst¹³¹, S. Dhaliwal¹⁰⁷, A. Di Ciaccio^{134a,134b}, L. Di Ciaccio⁵, A. Di Domenico^{133a,133b}, C. Di Donato^{104a,104b}, A. Di Girolamo³⁰, B. Di Girolamo³⁰, A. Di Mattia¹⁵³, B. Di Micco^{135a,135b}, R. Di Nardo⁴⁷, A. Di Simone⁴⁸, R. Di Sipio¹⁵⁹, D. Di Valentino²⁹, C. Diaconu⁸⁵, M. Diamond¹⁵⁹, F. A. Dias⁴⁶, M. A. Diaz^{32a}, E. B. Diehl⁸⁹, J. Dietrich¹⁶, T. A. Dietzsch^{58a}, S. Diglio⁸⁵, A. Dimitrievska¹³, J. Dingfelder²¹, F. Dittus³⁰, F. Djama⁸⁵, T. Djobava^{51b}, J. I. Djuvsland^{58a}, M. A. B. do Vale^{24c}, D. Dobos³⁰, M. Dobre^{26a}, C. Doglioni⁴⁹, T. Doherty⁵³, T. Dohmae¹⁵⁶, J. Dolejsi¹²⁹, Z. Dolezal¹²⁹, B. A. Dolgoshein^{98,*}, M. Donadelli^{24d}, S. Donati^{124a,124b}, P. Dondero^{121a,121b}, J. Donini³⁴, J. Dopke¹³¹, A. Doria^{104a}, M. T. Dova⁷¹, A. T. Doyle⁵³, M. Dris¹⁰, E. Dubreuil³⁴, E. Duchovni¹⁷³, G. Duckeck¹⁰⁰, O. A. Ducu^{26a}, D. Duda¹⁷⁶, A. Dudarev³⁰, L. Duflo¹¹⁷, L. Duguid⁷⁷, M. Dührssen³⁰, M. Dunford^{58a}, H. Duran Yildiz^{4a}, M. Düren⁵², A. Durglishvili^{51b}, D. Duschinger⁴⁴, M. Dwuznik^{38a}, M. Dyndal^{38a}, K. M. Ecker¹⁰¹, W. Edson², N. C. Edwards⁴⁶, W. Ehrenfeld²¹, T. Eifert³⁰, G. Eigen¹⁴, K. Einsweiler¹⁵, T. Ekelof¹⁶⁷, M. El Kacimi^{136c}, M. Ellert¹⁶⁷, S. Elles⁵, F. Ellinghaus⁸³, A. A. Elliot¹⁷⁰, N. Ellis³⁰, J. Elmsheuser¹⁰⁰, M. Elsing³⁰, D. Emelianov¹³¹, Y. Enari¹⁵⁶, O. C. Endner⁸³, M. Endo¹¹⁸, R. Engelmann¹⁴⁹, J. Erdmann⁴³, A. Ereditato¹⁷, D. Eriksson^{147a}, G. Ernis¹⁷⁶, J. Ernst², M. Ernst²⁵, S. Errede¹⁶⁶, E. Ertel⁸³, M. Escalier¹¹⁷, H. Esch⁴³, C. Escobar¹²⁵, B. Esposito⁴⁷, A. I. Etiennevire¹³⁷, E. Etzion¹⁵⁴, H. Evans⁶¹, A. Ezhilov¹²³, L. Fabbri^{20a,20b}, G. Facini³¹, R. M. Fakhruddinov¹³⁰, S. Falciano^{133a}, R. J. Falla⁷⁸, J. Faltova¹²⁹, Y. Fang^{33a}, M. Fanti^{91a,91b}, A. Farbin⁸, A. Farilla^{135a}, T. Farooque¹², S. Farrell¹⁵, S. M. Farrington¹⁷¹, P. Farthouat³⁰, F. Fassi^{136e}, P. Fassnacht³⁰, D. Fassoulotis⁹, A. Favareto^{50a,50b}, L. Fayard¹¹⁷, P. Federic^{145a}, O. L. Fedin^{123,m}, W. Fedorko¹⁶⁹, S. Feigl³⁰, L. Feligioni⁸⁵, C. Feng^{33d}, E. J. Feng⁶, H. Feng⁸⁹, A. B. Fenyuk¹³⁰, P. Fernandez Martinez¹⁶⁸, S. Fernandez Perez³⁰, S. Ferrag⁵³, J. Ferrando⁵³, A. Ferrari¹⁶⁷, P. Ferrari¹⁰⁷, R. Ferrari^{121a}, D. E. Ferreira de Lima⁵³, A. Ferrer¹⁶⁸, D. Ferrere⁴⁹, C. Ferretti⁸⁹,

- A. Ferretto Parodi^{50a,50b}, M. Fiascaris³¹, F. Fiedler⁸³, A. Filipčič⁷⁵, M. Filipuzzi⁴², F. Filthaut¹⁰⁶, M. Fincke-Keeler¹⁷⁰, K. D. Finelli¹⁵¹, M. C. N. Fiolhais^{126a,126c}, L. Fiorini¹⁶⁸, A. Firan⁴⁰, A. Fischer², C. Fischer¹², J. Fischer¹⁷⁶, W. C. Fisher⁹⁰, E. A. Fitzgerald²³, M. Flechl⁴⁸, I. Fleck¹⁴², P. Fleischmann⁸⁹, S. Fleischmann¹⁷⁶, G. T. Fletcher¹⁴⁰, G. Fletcher⁷⁶, T. Flick¹⁷⁶, A. Floderus⁸¹, L. R. Flores Castillo^{60a}, M. J. Flowerdew¹⁰¹, A. Formica¹³⁷, A. Forti⁸⁴, D. Fournier¹¹⁷, H. Fox⁷², S. Fracchia¹², P. Francavilla⁸⁰, M. Franchini^{20a,20b}, D. Francis³⁰, L. Franconi¹¹⁹, M. Franklin⁵⁷, M. Fraternali^{121a,121b}, D. Freeborn⁷⁸, S. T. French²⁸, F. Friedrich⁴⁴, D. Froidevaux³⁰, J. A. Frost¹²⁰, C. Fukunaga¹⁵⁷, E. Fullana Torregrosa⁸³, B. G. Fulsom¹⁴⁴, J. Fuster¹⁶⁸, C. Gabaldon⁵⁵, O. Gabizon¹⁷⁶, A. Gabrielli^{20a,20b}, A. Gabrielli^{133a,133b}, S. Gadatsch¹⁰⁷, S. Gadomski⁴⁹, G. Gagliardi^{50a,50b}, P. Gagnon⁶¹, C. Galea¹⁰⁶, B. Galhardo^{126a,126c}, E. J. Gallas¹²⁰, B. J. Gallop¹³¹, P. Gallus¹²⁸, G. Galster³⁶, K. K. Gan¹¹¹, J. Gao^{33b,85}, Y. S. Gao^{144,e}, F. M. Garay Walls⁴⁶, F. Garberson¹⁷⁷, C. García¹⁶⁸, J. E. García Navarro¹⁶⁸, M. Garcia-Sciveres¹⁵, R. W. Gardner³¹, N. Garelli¹⁴⁴, V. Garonne³⁰, C. Gatti⁴⁷, G. Gaudio^{121a}, B. Gaur¹⁴², L. Gauthier⁹⁵, P. Gauzzi^{133a,133b}, I. L. Gavrilenko⁹⁶, C. Gay¹⁶⁹, G. Gaycken²¹, E. N. Gazis¹⁰, P. Ge^{33d}, Z. Gecse¹⁶⁹, C. N. P. Gee¹³¹, D. A. A. Geerts¹⁰⁷, Ch. Geich-Gimbel²¹, C. Gemme^{50a}, M. H. Genest⁵⁵, S. Gentile^{133a,133b}, M. George⁵⁴, S. George⁷⁷, D. Gerbaudo¹⁶⁴, A. Gershon¹⁵⁴, H. Ghazlane^{136b}, N. Ghodbane³⁴, B. Giacobbe^{20a}, S. Giagu^{133a,133b}, V. Giangiobbe¹², P. Giannetti^{124a,124b}, F. Gianotti³⁰, B. Gibbard²⁵, S. M. Gibson⁷⁷, M. Gilchriese¹⁵, T. P. S. Gillam²⁸, D. Gillberg³⁰, G. Gilles³⁴, D. M. Gingrich^{3,d}, N. Giokaris⁹, M. P. Giordani^{165a,165c}, F. M. Giorgi^{20a}, F. M. Giorgi¹⁶, P. F. Giraud¹³⁷, D. Giugni^{91a}, C. Giuliani⁴⁸, M. Giulini^{58b}, B. K. Gjelsten¹¹⁹, S. Gkaitatzis¹⁵⁵, I. Gkialas¹⁵⁵, E. L. Gkougkousis¹¹⁷, L. K. Gladilin⁹⁹, C. Glasman⁸², J. Glatzer³⁰, P. C. F. Glaysheer⁴⁶, A. Glazov⁴², G. L. Glonti⁶², M. Goblirsch-Kolb¹⁰¹, J. R. Goddard⁷⁶, J. Godlewski³⁹, S. Goldfarb⁸⁹, T. Golling⁴⁹, D. Golubkov¹³⁰, A. Gomes^{126a,126b,126d}, R. Gonçalo^{126a}, J. Goncalves Pinto Firmino Da Costa¹³⁷, L. Gonella²¹, S. González de la Hoz¹⁶⁸, G. Gonzalez Parra¹², S. Gonzalez-Sevilla⁴⁹, L. Goossens³⁰, P. A. Gorbounov⁹⁷, H. A. Gordon²⁵, I. Gorelov¹⁰⁵, B. Gorini³⁰, E. Gorini^{73a,73b}, A. Gorišek⁷⁵, E. Gornicki³⁹, A. T. Goshaw⁴⁵, C. Gössling⁴³, M. I. Gostkin⁶⁵, M. Goughri^{136a}, D. Goujdami^{136c}, A. G. Goussiou¹³⁹, H. M. X. Grabas¹³⁸, L. Graber⁵⁴, I. Grabowska-Bold^{38a}, P. Grafström^{20a,20b}, K.-J. Grahm⁴², J. Gramling⁴⁹, E. Gramstad¹¹⁹, S. Grancagnolo¹⁶, V. Grassi¹⁴⁹, V. Gratchev¹²³, H. M. Gray³⁰, E. Graziani^{135a}, Z. D. Greenwood^{79,n}, K. Gregersen⁷⁸, I. M. Gregor⁴², P. Grenier¹⁴⁴, J. Griffiths⁸, A. A. Grillo¹³⁸, K. Grimm⁷², S. Grinstein^{12,o}, Ph. Gris³⁴, Y. V. Grishkevich⁹⁹, J.-F. Grivaz¹¹⁷, J. P. Grohs⁴⁴, A. Grohsjean⁴², E. Gross¹⁷³, J. Grosse-Knetter⁵⁴, G. C. Grossi^{134a,134b}, Z. J. Grout¹⁵⁰, L. Guan^{33b}, J. Guenther¹²⁸, F. Guescini⁴⁹, D. Guest¹⁷⁷, O. Gueta¹⁵⁴, E. Guido^{50a,50b}, T. Guillemin¹¹⁷, S. Guindon², U. Gul⁵³, C. Gumpert⁴⁴, J. Guo^{33e}, S. Gupta¹²⁰, P. Gutierrez¹¹³, N. G. Gutierrez Ortiz⁵³, C. Gutsche⁴⁴, N. Guttman¹⁵⁴, C. Guyot¹³⁷, C. Gwenlan¹²⁰, C. B. Gwilliam⁷⁴, A. Haas¹¹⁰, C. Haber¹⁵, H. K. Hadavand⁸, N. Haddad^{136c}, P. Haefner²¹, S. Hageböck²¹, Z. Hajduk³⁹, H. Hakobyan¹⁷⁸, M. Haleem⁴², J. Haley¹¹⁴, D. Hall¹²⁰, G. Halladjian⁹⁰, G. D. Hallewell⁸⁵, K. Hamacher¹⁷⁶, P. Hamal¹¹⁵, K. Hamano¹⁷⁰, M. Hamer⁵⁴, A. Hamilton^{146a}, S. Hamilton¹⁶², G. N. Hamity^{146c}, P. G. Hamnett⁴², L. Han^{33b}, K. Hanagaki¹¹⁸, K. Hanawa¹⁵⁶, M. Hance¹⁵, P. Hanke^{58a}, R. Hanna¹³⁷, J. B. Hansen³⁶, J. D. Hansen³⁶, P. H. Hansen³⁶, K. Hara¹⁶¹, A. S. Hard¹⁷⁴, T. Harenberg¹⁷⁶, F. Hariri¹¹⁷, S. Harkusha⁹², R. D. Harrington⁴⁶, P. F. Harrison¹⁷¹, F. Hartjes¹⁰⁷, M. Hasegawa⁶⁷, S. Hasegawa¹⁰³, Y. Hasegawa¹⁴¹, A. Hasib¹¹³, S. Hassani¹³⁷, S. Haug¹⁷, R. Hauser⁹⁰, L. Hauswald⁴⁴, M. Havranek¹²⁷, C. M. Hawkes¹⁸, R. J. Hawkins³⁰, A. D. Hawkins⁸¹, T. Hayashi¹⁶¹, D. Hayden⁹⁰, C. P. Hays¹²⁰, J. M. Hays⁷⁶, H. S. Hayward⁷⁴, S. J. Haywood¹³¹, S. J. Head¹⁸, T. Heck⁸³, V. Hedberg⁸¹, L. Heelan⁸, S. Heim¹²², T. Heim¹⁷⁶, B. Heinemann¹⁵, L. Heinrich¹¹⁰, J. Hejbal¹²⁷, L. Helary²², M. Heller³⁰, S. Hellman^{147a,147b}, D. Hellmich²¹, C. Helsens³⁰, J. Henderson¹²⁰, R. C. W. Henderson⁷², Y. Heng¹⁷⁴, C. Hengler⁴², A. Henrichs¹⁷⁷, A. M. Henriques Correia³⁰, S. Henrot-Versille¹¹⁷, G. H. Herbert¹⁶, Y. Hernández Jiménez¹⁶⁸, R. Herrberg-Schubert¹⁶, G. Herten⁴⁸, R. Hertenberger¹⁰⁰, L. Hervas³⁰, G. G. Hesketh⁷⁸, N. P. Hessey¹⁰⁷, R. Hickling⁷⁶, E. Higón-Rodríguez¹⁶⁸, E. Hill¹⁷⁰, J. C. Hill²⁸, K. H. Hiller⁴², S. J. Hillier¹⁸, I. Hinchliffe¹⁵, E. Hines¹²², R. R. Hinman¹⁵, M. Hirose¹⁵⁸, D. Hirschbuehl¹⁷⁶, J. Hobbs¹⁴⁹, N. Hod¹⁰⁷, M. C. Hodgkinson¹⁴⁰, P. Hodgson¹⁴⁰, A. Hoecker³⁰, M. R. Hoefkamp¹⁰⁵, F. Hoenig¹⁰⁰, M. Hohlfeld⁸³, T. R. Holmes¹⁵, T. M. Hong¹²², L. Hooft van Huysduynen¹¹⁰, W. H. Hopkins¹¹⁶, Y. Horii¹⁰³, A. J. Horton¹⁴³, J.-Y. Hostachy⁵⁵, S. Hou¹⁵², A. Hoummada^{136a}, J. Howard¹²⁰, J. Howarth⁴², M. Hrabovsky¹¹⁵, I. Hristova¹⁶, J. Hrivnac¹¹⁷, T. Hryn'ova⁵, A. Hrynevich⁹³, C. Hsu^{146c}, P. J. Hsu^{152,p}, S.-C. Hsu¹³⁹, D. Hu³⁵, Q. Hu^{33b}, X. Hu⁸⁹, Y. Huang⁴², Z. Hubacek³⁰, F. Hubaut⁸⁵, F. Huegging²¹, T. B. Huffman¹²⁰, E. W. Hughes³⁵, G. Hughes⁷², M. Huhtinen³⁰, T. A. Hülsing⁸³, N. Huseynov^{65,b}, J. Huston⁹⁰, J. Huth⁵⁷, G. Iacobucci⁴⁹, G. Iakovidis²⁵, I. Ibragimov¹⁴², L. Iconomidou-Fayard¹¹⁷, E. Ideal¹⁷⁷, Z. Idrissi^{136e}, P. Iengo^{104a}, O. Igonkina¹⁰⁷, T. Iizawa¹⁷², Y. Ikegami⁶⁶, K. Ikematsu¹⁴², M. Ikeno⁶⁶, Y. Ilchenko^{31,q}, D. Iliadis¹⁵⁵, N. Ilic¹⁵⁹, Y. Inamaru⁶⁷, T. Ince¹⁰¹, P. Ioannou⁹, M. Iodice^{135a}, K. Iordanidou⁹, V. Ippolito⁵⁷, A. Irls Quiles¹⁶⁸, C. Isaksson¹⁶⁷, M. Ishino⁶⁸, M. Ishitsuka¹⁵⁸, R. Ishmukhametov¹¹¹, C. Issever¹²⁰, S. Istin^{19a}, J. M. Iturbe Ponce⁸⁴, R. Iuppa^{134a,134b}, J. Ivarsson⁸¹, W. Iwanski³⁹, H. Iwasaki⁶⁶, J. M. Izen⁴¹, V. Izzo^{104a}, S. Jabbar³, B. Jackson¹²², M. Jackson⁷⁴, P. Jackson¹, M. R. Jaekel³⁰, V. Jain², K. Jakobs⁴⁸, S. Jakobsen³⁰, T. Jakoubek¹²⁷, J. Jakubek¹²⁸, D. O. Jamin¹⁵², D. K. Jana⁷⁹, E. Jansen⁷⁸, R. W. Jansky⁶², J. Janssen²¹, M. Janus¹⁷¹,

G. Jarlskog⁸¹, N. Javadov^{65,b}, T. Javůrek⁴⁸, L. Jeanty¹⁵, J. Jejelava^{51a,r}, G.-Y. Jeng¹⁵¹, D. Jennens⁸⁸, P. Jenni^{48,s}, J. Jentzsch⁴³, C. Jeske¹⁷¹, S. Jézéquel⁵, H. Ji¹⁷⁴, J. Jia¹⁴⁹, Y. Jiang^{33b}, J. Jimenez Pena¹⁶⁸, S. Jin^{33a}, A. Jinaru^{26a}, O. Jinnouchi¹⁵⁸, M. D. Joergensen³⁶, P. Johansson¹⁴⁰, K. A. Johns⁷, K. Jon-And^{147a,147b}, G. Jones¹⁷¹, R. W. L. Jones⁷², T. J. Jones⁷⁴, J. Jongmanns^{58a}, P. M. Jorge^{126a,126b}, K. D. Joshi⁸⁴, J. Jovicevic¹⁴⁸, X. Ju¹⁷⁴, C. A. Jung⁴³, P. Jussel⁶², A. Juste Rozas^{12,o}, M. Kaci¹⁶⁸, A. Kaczmarek³⁹, M. Kado¹¹⁷, H. Kagan¹¹¹, M. Kagan¹⁴⁴, S. J. Kahn⁸⁵, E. Kajomovitz⁴⁵, C. W. Kalderon¹²⁰, S. Kama⁴⁰, A. Kamenshchikov¹³⁰, N. Kanaya¹⁵⁶, M. Kaneda³⁰, S. Kaneti²⁸, V. A. Kantserov⁹⁸, J. Kanzaki⁶⁶, B. Kaplan¹¹⁰, A. Kapliy³¹, D. Kar⁵³, K. Karakostas¹⁰, A. Karamaoun³, N. Karastathis^{10,107}, M. J. Kareem⁵⁴, M. Karneviskiy⁸³, S. N. Karpov⁶⁵, Z. M. Karpova⁶⁵, K. Karthik¹¹⁰, V. Kartvelishvili⁷², A. N. Karyukhin¹³⁰, L. Kashif¹⁷⁴, R. D. Kass¹¹¹, A. Kastanas¹⁴, Y. Kataoka¹⁵⁶, A. Katre⁴⁹, J. Katzy⁴², K. Kawagoe⁷⁰, T. Kawamoto¹⁵⁶, G. Kawamura⁵⁴, S. Kazama¹⁵⁶, V. F. Kazanin^{109,c}, M. Y. Kazarinov⁶⁵, R. Keeler¹⁷⁰, R. Kehoe⁴⁰, M. Keil⁵⁴, J. S. Keller⁴², J. J. Kempster⁷⁷, H. Keoshkerian⁸⁴, O. Kepka¹²⁷, B. P. Kerševan⁷⁵, S. Kersten¹⁷⁶, R. A. Keyes⁸⁷, F. Khalil-zada¹¹, H. Khandanyan^{147a,147b}, A. Khanov¹¹⁴, A. G. Kharlamov^{109,c}, A. Khodinov⁹⁸, A. Khomich^{58a}, T. J. Khoo²⁸, G. Khorauli²¹, V. Khovanskiy⁹⁷, E. Khramov⁶⁵, J. Khubua^{51b,t}, H. Y. Kim⁸, H. Kim^{147a,147b}, S. H. Kim¹⁶¹, Y. Kim³¹, N. Kimura¹⁵⁵, O. Kind¹⁶, B. T. King⁷⁴, M. King¹⁶⁸, R. S. B. King¹²⁰, S. B. King¹⁶⁹, J. Kirk¹³¹, A. E. Kiryunin¹⁰¹, T. Kishimoto⁶⁷, D. Kisieleska^{38a}, F. Kiss⁴⁸, K. Kiuchi¹⁶¹, E. Kladrava^{145b}, M. H. Klein³⁵, M. Klein⁷⁴, U. Klein⁷⁴, K. Kleinknecht⁸³, P. Klimek^{147a,147b}, A. Klimentov²⁵, R. Klingenberg⁴³, J. A. Klinger⁸⁴, T. Kliuchnikov³⁰, P. F. Klok¹⁰⁶, E.-E. Kluge^{58a}, P. Kluit¹⁰⁷, S. Kluth¹⁰¹, E. Kneringer⁶², E. B. F. G. Knoops⁸⁵, A. Knue⁵³, D. Kobayashi¹⁵⁸, T. Kobayashi¹⁵⁶, M. Kobel⁴⁴, M. Kocian¹⁴⁴, P. Kodys¹²⁹, T. Koffas²⁹, E. Koffeman¹⁰⁷, L. A. Kogan¹²⁰, S. Kohlmann¹⁷⁶, Z. Kohout¹²⁸, T. Kohriki⁶⁶, T. Koi¹⁴⁴, H. Kolanoski¹⁶, I. Koletsou⁵, A. A. Komar^{96,*}, Y. Komori¹⁵⁶, T. Kondo⁶⁶, N. Kondrashova⁴², K. Köneke⁴⁸, A. C. König¹⁰⁶, S. König⁸³, T. Kono^{66,u}, R. Konoplich^{110,v}, N. Konstantinidis⁷⁸, R. Kopeliansky¹⁵³, S. Koperny^{38a}, L. Köpke⁸³, A. K. Kopp⁴⁸, K. Korcyl³⁹, K. Kordas¹⁵⁵, A. Korn⁷⁸, A. A. Korol^{109,c}, I. Korolkov¹², E. V. Korolkova¹⁴⁰, O. Kortner¹⁰¹, S. Kortner¹⁰¹, T. Kosek¹²⁹, V. V. Kostyukhin²¹, V. M. Kotov⁶⁵, A. Kotwal⁴⁵, A. Kourkoumeli-Charalampidi¹⁵⁵, C. Kourkoumelis⁹, V. Kouskoura²⁵, A. Koutsman^{160a}, R. Kowalewski¹⁷⁰, T. Z. Kowalski^{38a}, W. Kozanecki¹³⁷, A. S. Kozhin¹³⁰, V. A. Kramarenko⁹⁹, G. Kramberger⁷⁵, D. Krasnopevtsev⁹⁸, M. W. Krasny⁸⁰, A. Krasznahorkay³⁰, J. K. Kraus²¹, A. Kravchenko²⁵, S. Kreiss¹¹⁰, M. Kretz^{58c}, J. Kretzschmar⁷⁴, K. Kreutzfeldt⁵², P. Krieger¹⁵⁹, K. Krizka³¹, K. Kroeninger⁴³, H. Kroha¹⁰¹, J. Kroll¹²², J. Kroseberg²¹, J. Krstic¹³, U. Kruchonak⁶⁵, H. Krüger²¹, N. Krumnack⁶⁴, Z. V. Krumshteyn⁶⁵, A. Kruse¹⁷⁴, M. C. Kruse⁴⁵, M. Kruskal²², T. Kubota⁸⁸, H. Kucuk⁷⁸, S. Kuday^{4c}, S. Kuehn⁴⁸, A. Kugel^{58c}, F. Kuger¹⁷⁵, A. Kuhl¹³⁸, T. Kuhl⁴², V. Kukhtin⁶⁵, Y. Kulchitsky⁹², S. Kuleshov^{32b}, M. Kuna^{133a,133b}, T. Kunigo⁶⁸, A. Kupco¹²⁷, H. Kurashige⁶⁷, Y. A. Kurochkin⁹², R. Kurumida⁶⁷, V. Kus¹²⁷, E. S. Kuwertz¹⁴⁸, M. Kuze¹⁵⁸, J. Kvita¹¹⁵, T. Kwan¹⁷⁰, D. Kyriazopoulos¹⁴⁰, A. La Rosa⁴⁹, J. L. La Rosa Navarro^{24d}, L. La Rotonda^{37a,37b}, C. Lacasta¹⁶⁸, F. Lacava^{133a,133b}, J. Lacey²⁹, H. Lacker¹⁶, D. Lacour⁸⁰, V. R. Lacuesta¹⁶⁸, E. Ladygin⁶⁵, R. Lafaye⁵, B. Laforge⁸⁰, T. Lagouri¹⁷⁷, S. Lai⁴⁸, L. Lambourne⁷⁸, S. Lammers⁶¹, C. L. Lampen⁷, W. Lampl⁷, E. Lançon¹³⁷, U. Landgraf⁴⁸, M. P. J. Landon⁷⁶, V. S. Lang^{58a}, A. J. Lankford¹⁶⁴, F. Lanni²⁵, K. Lantzsch³⁰, S. Laplace⁸⁰, C. Lapoire³⁰, J. F. Laporte¹³⁷, T. Lari^{91a}, F. Lasagni Manghi^{20a,20b}, M. Lassnig³⁰, P. Laurelli⁴⁷, W. Lavrijsen¹⁵, A. T. Law¹³⁸, P. Laycock⁷⁴, O. Le Dortz⁸⁰, E. Le Guirriec⁸⁵, E. Le Menedeu¹², T. LeCompte⁶, F. Ledroit-Guillon⁵⁵, C. A. Lee^{146b}, S. C. Lee¹⁵², L. Lee¹, G. Lefebvre⁸⁰, M. Lefebvre¹⁷⁰, F. Legger¹⁰⁰, C. Leggett¹⁵, A. Lehan⁷⁴, G. Lehmann Miotto³⁰, X. Lei⁷, W. A. Leight²⁹, A. Leisos¹⁵⁵, A. G. Leister¹⁷⁷, M. A. L. Leite^{24d}, R. Leitner¹²⁹, D. Lellouch¹⁷³, B. Lemmer⁵⁴, K. J. C. Leney⁷⁸, T. Lenz²¹, G. Lenzen¹⁷⁶, B. Lenzi³⁰, R. Leone⁷, S. Leone^{124a,124b}, C. Leonidopoulos⁴⁶, S. Leontsinis¹⁰, C. Leroy⁹⁵, C. G. Lester²⁸, M. Levchenko¹²³, J. Levêque⁵, D. Levin⁸⁹, L. J. Levinson¹⁷³, M. Levy¹⁸, A. Lewis¹²⁰, A. M. Leyko²¹, M. Leyton⁴¹, B. Li^{33b,w}, B. Li⁸⁵, H. Li¹⁴⁹, H. L. Li³¹, L. Li⁴⁵, L. Li^{33c}, S. Li⁴⁵, Y. Li^{33c,x}, Z. Liang¹³⁸, H. Liao³⁴, B. Liberti^{134a}, P. Lichard³⁰, K. Lie¹⁶⁶, J. Liebal²¹, W. Liebig¹⁴, C. Limbach²¹, A. Limosani¹⁵¹, S. C. Lin^{152,y}, T. H. Lin⁸³, F. Linde¹⁰⁷, B. E. Lindquist¹⁴⁹, J. T. Linnemann⁹⁰, E. Lipeles¹²², A. Lipniacka¹⁴, M. Lisovyi⁴², T. M. Liss¹⁶⁶, D. Lissauer²⁵, A. Lister¹⁶⁹, A. M. Litke¹³⁸, B. Liu¹⁵², D. Liu¹⁵², J. Liu⁸⁵, J. B. Liu^{33b}, K. Liu⁸⁵, L. Liu⁸⁹, M. Liu⁴⁵, M. Liu^{33b}, Y. Liu^{33b}, M. Livan^{121a,121b}, A. Lleres⁵⁵, J. Llorente Merino⁸², S. L. Lloyd⁷⁶, F. Lo Sterzo¹⁵², E. Lobodzinska⁴², P. Loch⁷, W. S. Lockman¹³⁸, F. K. Loebinger⁸⁴, A. E. Loevschall-Jensen³⁶, A. Loginov¹⁷⁷, T. Lohse¹⁶, K. Lohwasser⁴², M. Lokajicek¹²⁷, B. A. Long²², J. D. Long⁸⁹, R. E. Long⁷², K. A. Looper¹¹¹, L. Lopes^{126a}, D. Lopez Mateos⁵⁷, B. Lopez Paredes¹⁴⁰, I. Lopez Paz¹², J. Lorenz¹⁰⁰, N. Lorenzo Martinez⁶¹, M. Losada¹⁶³, P. Loscutoff¹⁵, P. J. Lösel¹⁰⁰, X. Lou^{33a}, A. Lounis¹¹⁷, J. Love⁶, P. A. Love⁷², N. Lu⁸⁹, H. J. Lubatti¹³⁹, C. Luci^{133a,133b}, A. Lucotte⁵⁵, F. Luehring⁶¹, W. Lukas⁶², L. Luminari^{133a}, O. Lundberg^{147a,147b}, B. Lund-Jensen¹⁴⁸, M. Lungwitz⁸³, D. Lynn²⁵, R. Lysak¹²⁷, E. Lytken⁸¹, H. Ma²⁵, L. L. Ma^{33d}, G. Maccarrone⁴⁷, A. Macchiolo¹⁰¹, C. M. Macdonald¹⁴⁰, J. Machado Mi guens^{126a,126b}, D. Macina³⁰, D. Madaffari⁸⁵, R. Madar³⁴, H. J. Maddocks⁷², W. F. Mader⁴⁴, A. Madsen¹⁶⁷, T. Maeno²⁵, A. Maevskiy⁹⁹, E. Magradze⁵⁴, K. Mahboubi⁴⁸, J. Mahlstedt¹⁰⁷, S. Mahmoud⁷⁴, C. Maiani¹³⁷, C. Maidantchik^{24a}, A. A. Maier¹⁰¹, T. Maier¹⁰⁰, A. Maio^{126a,126b,126d}, S. Majewski¹¹⁶, Y. Makida⁶⁶, N. Makovec¹¹⁷, B. Malaescu⁸⁰, Pa. Malecki³⁹, V. P. Maleev¹²³, F. Malek⁵⁵, U. Mallik⁶³,

D. Malon⁶, C. Malone¹⁴⁴, S. Maltezos¹⁰, V. M. Malyshev¹⁰⁹, S. Malyukov³⁰, J. Mamuzic⁴², G. Mancini⁴⁷, B. Mandelli³⁰, L. Mandelli^{91a}, I. Mandić⁷⁵, R. Mandrysch⁶³, J. Maneira^{126a,126b}, A. Manfredini¹⁰¹, L. Manhaes de Andrade Filho^{24b}, J. Majarres Ramos^{160b}, A. Mann¹⁰⁰, P. M. Manning¹³⁸, A. Manousakis-Katsikakis⁹, B. Mansoulie¹³⁷, R. Mantifel⁸⁷, M. Mantoani⁵⁴, L. Mapelli³⁰, L. March^{146c}, G. Marchiori⁸⁰, M. Marcisovsky¹²⁷, C. P. Marino¹⁷⁰, M. Marjanovic¹³, F. Marroquim^{24a}, S. P. Marsden⁸⁴, Z. Marshall¹⁵, L. F. Marti¹⁷, S. Marti-Garcia¹⁶⁸, B. Martin⁹⁰, T. A. Martin¹⁷¹, V. J. Martin⁴⁶, B. Martin dit Latour¹⁴, H. Martinez¹³⁷, M. Martinez^{12,o}, S. Martin-Haugh¹³¹, V. S. Martoiu^{26a}, A. C. Martyniuk⁷⁸, M. Marx¹³⁹, F. Marzano^{133a}, A. Marzin³⁰, L. Masetti⁸³, T. Mashimo¹⁵⁶, R. Mashinistov⁹⁶, J. Masik⁸⁴, A. L. Maslennikov^{109,c}, I. Massa^{20a,20b}, L. Massa^{20a,20b}, N. Massol⁵, P. Mastrandrea¹⁴⁹, A. Mastroberardino^{37a,37b}, T. Masubuchi¹⁵⁶, P. Mättig¹⁷⁶, J. Mattmann⁸³, J. Maurer^{26a}, S. J. Maxfield⁷⁴, D. A. Maximov^{109,c}, R. Mazini¹⁵², S. M. Mazza^{91a,91b}, L. Mazzaferro^{134a,134b}, G. Mc Goldrick¹⁵⁹, S. P. Mc Kee⁸⁹, A. McCarn⁸⁹, R. L. McCarthy¹⁴⁹, T. G. McCarthy²⁹, N. A. McCubbin¹³¹, K. W. McFarlane^{56,*}, J. A. Mcfayden⁷⁸, G. Mchedlidze⁵⁴, S. J. McMahon¹³¹, R. A. McPherson^{170,k}, J. Mechnich¹⁰⁷, M. Medinnis⁴², S. Meehan^{146a}, S. Mehlhase¹⁰⁰, A. Mehta⁷⁴, K. Meier^{58a}, C. Meineck¹⁰⁰, B. Meirose⁴¹, C. Melachrinou³¹, B. R. Mellado Garcia^{146c}, F. Meloni¹⁷, A. Mengarelli^{20a,20b}, S. Menke¹⁰¹, E. Meoni¹⁶², K. M. Mercurio⁵⁷, S. Mergelmeyer²¹, N. Meric¹³⁷, P. Mermod⁴⁹, L. Merola^{104a,104b}, C. Meroni^{91a}, F. S. Merritt³¹, H. Merritt¹¹¹, A. Messina^{30,z}, J. Metcalfe²⁵, A. S. Mete¹⁶⁴, C. Meyer⁸³, C. Meyer¹²², J-P. Meyer¹³⁷, J. Meyer¹⁰⁷, R. P. Middleton¹³¹, S. Migas⁷⁴, S. Miglioranza^{165a,165c}, L. Mijović²¹, G. Mikenberg¹⁷³, M. Mikesikova¹²⁷, M. Mikuž⁷⁵, A. Milic³⁰, D. W. Miller³¹, C. Mills⁴⁶, A. Milov¹⁷³, D. A. Milstead^{147a,147b}, A. A. Minaenko¹³⁰, Y. Minami¹⁵⁶, I. A. Minashvili⁶⁵, A. I. Mincer¹¹⁰, B. Mindur^{38a}, M. Mineev⁶⁵, Y. Ming¹⁷⁴, L. M. Mir¹², G. Mirabelli^{133a}, T. Mitani¹⁷², J. Mitrevski¹⁰⁰, V. A. Mitsou¹⁶⁸, A. Miucci⁴⁹, P. S. Miyagawa¹⁴⁰, J. U. Mjörnmark⁸¹, T. Moa^{147a,147b}, K. Mochizuki⁸⁵, S. Mohapatra³⁵, W. Mohr⁴⁸, S. Molander^{147a,147b}, R. Moles-Valls¹⁶⁸, K. Mönig⁴², C. Monini⁵⁵, J. Monk³⁶, E. Monnier⁸⁵, J. Montejo Berlingen¹², F. Monticelli⁷¹, S. Monzani^{133a,133b}, R. W. Moore³, N. Morange¹¹⁷, D. Moreno¹⁶³, M. Moreno Llacer⁵⁴, P. Morettini^{50a}, M. Morgenstern⁴⁴, M. Morii⁵⁷, V. Morisbak¹¹⁹, S. Moritz⁸³, A. K. Morley¹⁴⁸, G. Mornacchi³⁰, J. D. Morris⁷⁶, A. Morton⁵³, L. Morvaj¹⁰³, H. G. Moser¹⁰¹, M. Mosidze^{51b}, J. Moss¹¹¹, K. Motohashi¹⁵⁸, R. Mount¹⁴⁴, E. Mountricha²⁵, S. V. Mouraviev^{96,*}, E. J. W. Moyse⁸⁶, S. Muanza⁸⁵, R. D. Mudd¹⁸, F. Mueller¹⁰¹, J. Mueller¹²⁵, K. Mueller²¹, R. S. P. Mueller¹⁰⁰, T. Mueller²⁸, D. Muenstermann⁴⁹, P. Mullen⁵³, Y. Munwes¹⁵⁴, J. A. Murillo Quijada¹⁸, W. J. Murray^{171,131}, H. Musheghyan⁵⁴, E. Musto¹⁵³, A. G. Myagkov^{130,aa}, M. Myska¹²⁸, O. Nackenhorst⁵⁴, J. Nadal⁵⁴, K. Nagai¹²⁰, R. Nagai¹⁵⁸, Y. Nagai⁸⁵, K. Nagano⁶⁶, A. Nagarkar¹¹¹, Y. Nagasaka⁵⁹, K. Nagata¹⁶¹, M. Nagel¹⁰¹, E. Nagy⁸⁵, A. M. Nairz³⁰, Y. Nakahama³⁰, K. Nakamura⁶⁶, T. Nakamura¹⁵⁶, I. Nakano¹¹², H. Namasivayam⁴¹, G. Nanava²¹, R. F. Naranjo Garcia⁴², R. Narayan^{58b}, T. Nattermann²¹, T. Naumann⁴², G. Navarro¹⁶³, R. Nayyar⁷, H. A. Neal⁸⁹, P. Yu. Nechaeva⁹⁶, T. J. Neep⁸⁴, P. D. Nef¹⁴⁴, A. Negri^{121a,121b}, M. Negrini^{20a}, S. Nektarijevic¹⁰⁶, C. Nellist¹¹⁷, A. Nelson¹⁶⁴, S. Nemecek¹²⁷, P. Nemethy¹¹⁰, A. A. Nepomuceno^{24a}, M. Nessi^{30,ab}, M. S. Neubauer¹⁶⁶, M. Neumann¹⁷⁶, R. M. Neves¹¹⁰, P. Nevski²⁵, P. R. Newman¹⁸, D. H. Nguyen⁶, R. B. Nickerson¹²⁰, R. Nicolaïdou¹³⁷, B. Nicquevert³⁰, J. Nielsen¹³⁸, N. Nikiforou³⁵, A. Nikiforov¹⁶, V. Nikolaenko^{130,aa}, I. Nikolic-Audit⁸⁰, K. Nikolopoulos¹⁸, P. Nilsson²⁵, Y. Ninomiya¹⁵⁶, A. Nisati^{133a}, R. Nisius¹⁰¹, T. Nobe¹⁵⁸, M. Nomachi¹¹⁸, I. Nomidis²⁹, T. Nooney⁷⁶, S. Norberg¹¹³, M. Nordberg³⁰, O. Novgorodova⁴⁴, S. Nowak¹⁰¹, M. Nozaki⁶⁶, L. Nozka¹¹⁵, K. Ntekas¹⁰, G. Nunes Hanninger⁸⁸, T. Nunnemann¹⁰⁰, E. Nurse⁷⁸, F. Nuti⁸⁸, B. J. O'Brien⁴⁶, F. O'grady⁷, D. C. O'Neil¹⁴³, V. O'Shea⁵³, F. G. Oakham^{29,d}, H. Oberlack¹⁰¹, T. Obermann²¹, J. Ocariz⁸⁰, A. Ochi⁶⁷, I. Ochoa⁷⁸, S. Oda⁷⁰, S. Odaka⁶⁶, H. Ogren⁶¹, A. Oh⁸⁴, S. H. Oh⁴⁵, C. C. Ohm¹⁵, H. Ohman¹⁶⁷, H. Oide³⁰, W. Okamura¹¹⁸, H. Okawa¹⁶¹, Y. Okumura³¹, T. Okuyama¹⁵⁶, A. Olariu^{26a}, S. A. Olivares Pino⁴⁶, D. Oliveira Damazio²⁵, E. Oliver Garcia¹⁶⁸, A. Olszewski³⁹, J. Olszowska³⁹, A. Onofre^{126a,126c}, P. U. E. Onyisi^{31,q}, C. J. Oram^{160a}, M. J. Oreglia³¹, Y. Oren¹⁵⁴, D. Orestano^{135a,135b}, N. Orlando¹⁵⁵, C. Oropeza Barrera⁵³, R. S. Orr¹⁵⁹, B. Osculati^{50a,50b}, R. Ospanov⁸⁴, G. Otero y Garzon²⁷, H. Otono⁷⁰, M. Ouchrif^{136d}, E. A. Ouellette¹⁷⁰, F. Ould-Saada¹¹⁹, A. Ouraou¹³⁷, K. P. Oussoren¹⁰⁷, Q. Ouyang^{33a}, A. Ovcharova¹⁵, M. Owen⁵³, R. E. Owen¹⁸, V. E. Ozcan^{19a}, N. Ozturk⁸, K. Pachal¹²⁰, A. Pacheco Pages¹², C. Padilla Aranda¹², M. Pagáčová⁴⁸, S. Pagan Griso¹⁵, E. Paganis¹⁴⁰, C. Pahl¹⁰¹, F. Paige²⁵, P. Pais⁸⁶, K. Pajchel¹¹⁹, G. Palacino^{160b}, S. Palestini³⁰, M. Palka^{38b}, D. Pallin³⁴, A. Palma^{126a,126b}, Y. B. Pan¹⁷⁴, E. Panagiotopoulou¹⁰, C. E. Pandini⁸⁰, J. G. Panduro Vazquez⁷⁷, P. Pani^{147a,147b}, S. Panitkin²⁵, L. Paolozzi^{134a,134b}, Th. D. Papadopoulos¹⁰, K. Papageorgiou¹⁵⁵, A. Paramonov⁶, D. Paredes Hernandez¹⁵⁵, M. A. Parker²⁸, K. A. Parker¹⁴⁰, F. Parodi^{50a,50b}, J. A. Parsons³⁵, U. Parzefall⁴⁸, E. Pasqualucci^{133a}, S. Passaggio^{50a}, F. Pastore^{135a,135b}, Fr. Pastore⁷⁷, G. Pásztor²⁹, S. Patariaia¹⁷⁶, N. D. Patel¹⁵¹, J. R. Pater⁸⁴, T. Pauly³⁰, J. Pearce¹⁷⁰, B. Pearson¹¹³, L. E. Pedersen³⁶, M. Pedersen¹¹⁹, S. Pedraza Lopez¹⁶⁸, R. Pedro^{126a,126b}, S. V. Peleganchuk¹⁰⁹, D. Pelikan¹⁶⁷, H. Peng^{33b}, B. Penning³¹, J. Penwell⁶¹, D. V. Perepelitsa²⁵, E. Perez Codina^{160a}, M. T. Pérez García-Están¹⁶⁸, L. Perini^{91a,91b}, H. Pernegger³⁰, S. Perrella^{104a,104b}, R. Peschke⁴², V. D. Peshekhonov⁶⁵, K. Peters³⁰, R. F. Y. Peters⁸⁴, B. A. Petersen³⁰, T. C. Petersen³⁶, E. Petit⁴², A. Petridis^{147a,147b}, C. Petridou¹⁵⁵, E. Petrolu^{133a}, F. Petrucci^{135a,135b}, N. E. Pettersson¹⁵⁸, R. Pezoa^{32b}, P. W. Phillips¹³¹, G. Piacquadio¹⁴⁴,

E. Pianori¹⁷¹, A. Picazio⁴⁹, E. Piccaro⁷⁶, M. Piccinini^{20a,20b}, M. A. Pickering¹²⁰, R. Piegaia²⁷, D. T. Pignotti¹¹¹, J. E. Pilcher³¹, A. D. Pilkington⁷⁸, J. Pina^{126a,126b,126d}, M. Pinamonti^{165a,165c,ac}, J. L. Pinfold³, A. Pingel³⁶, B. Pinto^{126a}, S. Pires⁸⁰, M. Pitt¹⁷³, C. Pizio^{91a,91b}, L. Plazak^{145a}, M.-A. Pleier²⁵, V. Pleskot¹²⁹, E. Plotnikova⁶⁵, P. Plucinski^{147a,147b}, D. Pluth⁶⁴, R. Poettgen⁸³, L. Poggioli¹¹⁷, D. Pohl²¹, G. Polesello^{121a}, A. Policicchio^{37a,37b}, R. Polifka¹⁵⁹, A. Polini^{20a}, C. S. Pollard⁵³, V. Polychronakos²⁵, K. Pommès³⁰, L. Pontecorvo^{133a}, B. G. Pope⁹⁰, G. A. Popeneciu^{26b}, D. S. Popovic¹³, A. Poppleton³⁰, S. Pospisil¹²⁸, K. Potamianos¹⁵, I. N. Potrap⁶⁵, C. J. Potter¹⁵⁰, C. T. Potter¹¹⁶, G. Poulard³⁰, J. Poveda³⁰, V. Pozdnyakov⁶⁵, P. Pralavorio⁸⁵, A. Pranko¹⁵, S. Prasad³⁰, S. Prell⁶⁴, D. Price⁸⁴, J. Price⁷⁴, L. E. Price⁶, M. Primavera^{73a}, S. Prince⁸⁷, M. Proissl⁴⁶, K. Prokofiev^{60c}, F. Prokoshin^{32b}, E. Protopapadaki¹³⁷, S. Protopopescu²⁵, J. Proudfoot⁶, M. Przybycien^{38a}, E. Ptacek¹¹⁶, D. Puddu^{135a,135b}, E. Pueschel⁸⁶, D. Puldon¹⁴⁹, M. Purohit^{25,ad}, P. Puzo¹¹⁷, J. Qian⁸⁹, G. Qin⁵³, Y. Qin⁸⁴, A. Quadt⁵⁴, D. R. Quarrie¹⁵, W. B. Quayle^{165a,165b}, M. Queitsch-Maitland⁸⁴, D. Quilty⁵³, A. Qureshi^{160b}, V. Radeka²⁵, V. Radescu⁴², S. K. Radhakrishnan¹⁴⁹, P. Radloff¹¹⁶, P. Rados⁸⁸, F. Ragusa^{91a,91b}, G. Rahal¹⁷⁹, S. Rajagopalan²⁵, M. Rammensee³⁰, C. Rangel-Smith¹⁶⁷, F. Rauscher¹⁰⁰, S. Rave⁸³, T. C. Rave⁴⁸, T. Ravenscroft⁵³, M. Raymond³⁰, A. L. Read¹¹⁹, N. P. Readioff⁷⁴, D. M. Rebuffi^{121a,121b}, A. Redelbach¹⁷⁵, G. Redlinger²⁵, R. Reece¹³⁸, K. Reeves⁴¹, L. Rehnisch¹⁶, H. Reisin²⁷, M. Relich¹⁶⁴, C. Rembsen³⁰, H. Ren^{33a}, A. Renaud¹¹⁷, M. Rescigno^{133a}, S. Resconi^{91a}, O. L. Rezanova^{109,c}, P. Reznicek¹²⁹, R. Rezvani⁹⁵, R. Richter¹⁰¹, E. Richter-Was^{38b}, M. Ridel⁸⁰, P. Rieck¹⁶, C. J. Riegel¹⁷⁶, J. Rieger⁵⁴, M. Rijssenbeek¹⁴⁹, A. Rimoldi^{121a,121b}, L. Rinaldi^{20a}, E. Ritsch⁶², I. Riu¹², F. Rizatdinova¹¹⁴, E. Rizvi⁷⁶, S. H. Robertson^{87,k}, A. Robichaud-Veronneau⁸⁷, D. Robinson²⁸, J. E. M. Robinson⁸⁴, A. Robson⁵³, C. Roda^{124a,124b}, L. Rodrigues³⁰, S. Roe³⁰, O. Røhne¹¹⁹, S. Rolli¹⁶², A. Romaniouk⁹⁸, M. Romano^{20a,20b}, S. M. Romano Saez³⁴, E. Romero Adam¹⁶⁸, N. Rompotis¹³⁹, M. Ronzani⁴⁸, L. Roos⁸⁰, E. Ros¹⁶⁸, S. Rosati^{133a}, K. Rosbach⁴⁸, P. Rose¹³⁸, P. L. Rosendahl¹⁴, O. Rosenthal¹⁴², V. Rossetti^{147a,147b}, E. Rossi^{104a,104b}, L. P. Rossi^{50a}, R. Rosten¹³⁹, M. Rotaru^{26a}, I. Roth¹⁷³, J. Rothberg¹³⁹, D. Rousseau¹¹⁷, C. R. Royon¹³⁷, A. Rozanov⁸⁵, Y. Rozen¹⁵³, X. Ruan^{146c}, F. Rubbo¹⁴⁴, I. Rubinskiy⁴², V. I. Rud⁹⁹, C. Rudolph⁴⁴, M. S. Rudolph¹⁵⁹, F. Rühr⁴⁸, A. Ruiz-Martinez³⁰, Z. Rurikova⁴⁸, N. A. Rusakovich⁶⁵, A. Ruschke¹⁰⁰, H. L. Russell¹³⁹, J. P. Rutherford⁷, N. Ruthmann⁴⁸, Y. F. Ryabov¹²³, M. Rybar¹²⁹, G. Rybkin¹¹⁷, N. C. Ryder¹²⁰, A. F. Saavedra¹⁵¹, G. Sabato¹⁰⁷, S. Sacerdoti²⁷, A. Saddique³, H. F.-W. Sadrozinski¹³⁸, R. Sadykov⁶⁵, F. Safai Tehrani^{133a}, M. Saimpert¹³⁷, H. Sakamoto¹⁵⁶, Y. Sakurai¹⁷², G. Salamanna^{135a,135b}, A. Salamon^{134a}, M. Saleem¹¹³, D. Salek¹⁰⁷, P. H. Sales De Bruin¹³⁹, D. Salihagic¹⁰¹, A. Salnikov¹⁴⁴, J. Salt¹⁶⁸, D. Salvatore^{37a,37b}, F. Salvatore¹⁵⁰, A. Salvucci¹⁰⁶, A. Salzburger³⁰, D. Sampsonidis¹⁵⁵, A. Sanchez^{104a,104b}, J. Sánchez¹⁶⁸, V. Sanchez Martinez¹⁶⁸, H. Sandaker¹⁴, R. L. Sandbach⁷⁶, H. G. Sander⁸³, M. P. Sanders¹⁰⁰, M. Sandhoff¹⁷⁶, C. Sandoval¹⁶³, R. Sandstroem¹⁰¹, D. P. C. Sankey¹³¹, A. Sansoni⁴⁷, C. Santoni³⁴, R. Santonico^{134a,134b}, H. Santos^{126a}, I. Santoyo Castillo¹⁵⁰, K. Sapp¹²⁵, A. Sapronov⁶⁵, J. G. Saraiva^{126a,126d}, B. Sarrazin²¹, O. Sasaki⁶⁶, Y. Sasaki¹⁵⁶, K. Sato¹⁶¹, G. Sauvage^{5,*}, E. Sauvan⁵, G. Savage⁷⁷, P. Savard^{159,d}, C. Sawyer¹²⁰, L. Sawyer^{79,n}, D. H. Saxon⁵³, J. Saxon³¹, C. Sbarra^{20a}, A. Sbrizzi^{20a,20b}, T. Scanlon⁷⁸, D. A. Scannicchio¹⁶⁴, M. Scarcella¹⁵¹, V. Scarfone^{37a,37b}, J. Schaarschmidt¹⁷³, P. Schacht¹⁰¹, D. Schaefer³⁰, R. Schaefer⁴², J. Schaeffer⁸³, S. Schaepe²¹, S. Schaetzel^{58b}, U. Schäfer⁸³, A. C. Schaffer¹¹⁷, D. Schaile¹⁰⁰, R. D. Schamberger¹⁴⁹, V. Scharf^{58a}, V. A. Schegelsky¹²³, D. Scheirich¹²⁹, M. Schernau¹⁶⁴, C. Schiavi^{50a,50b}, C. Schillo⁴⁸, M. Schioppa^{37a,37b}, S. Schlenker³⁰, E. Schmidt⁴⁸, K. Schmieden³⁰, C. Schmitt⁸³, S. Schmitt^{58b}, S. Schmitt⁴², B. Schneider^{160a}, Y. J. Schnellbach⁷⁴, U. Schnoor⁴⁴, L. Schoeffel¹³⁷, A. Schoening^{58b}, B. D. Schoenrock⁹⁰, A. L. S. Schorlemmer⁵⁴, M. Schott⁸³, D. Schouten^{160a}, J. Schovancova⁸, S. Schramm¹⁵⁹, M. Schreyer¹⁷⁵, C. Schroeder⁸³, N. Schuh⁸³, M. J. Schultens²¹, H.-C. Schultz-Coulon^{58a}, H. Schulz¹⁶, M. Schumacher⁴⁸, B. A. Schumm¹³⁸, Ph. Schune¹³⁷, C. Schwanenberger⁸⁴, A. Schwartzman¹⁴⁴, T. A. Schwarz⁸⁹, Ph. Schwegler¹⁰¹, Ph. Schwemling¹³⁷, R. Schwienhorst⁹⁰, J. Schwindling¹³⁷, T. Schwindt²¹, M. Schwoerer⁵, F. G. Sciaccia¹⁷, E. Scifo¹¹⁷, G. Sciolla²³, F. Scuri^{124a,124b}, F. Scutti²¹, J. Searcy⁸⁹, G. Sedov⁴², E. Sedykh¹²³, P. Seema²¹, S. C. Seidel¹⁰⁵, A. Seiden¹³⁸, F. Seifert¹²⁸, J. M. Seixas^{24a}, G. Sekhniaidze^{104a}, S. J. Sekula⁴⁰, K. E. Selbach⁴⁶, D. M. Seliverstov^{123,*}, N. Semprini-Cesari^{20a,20b}, C. Serfon³⁰, L. Serin¹¹⁷, L. Serkin⁵⁴, T. Serre⁸⁵, R. Seuster^{160a}, H. Severini¹¹³, T. Sfiligoj⁷⁵, F. Sforza¹⁰¹, A. Sfyrila³⁰, E. Shabalina⁵⁴, M. Shamim¹¹⁶, L. Y. Shan^{33a}, R. Shang¹⁶⁶, J. T. Shank²², M. Shapiro¹⁵, P. B. Shatalov⁹⁷, K. Shaw^{165a,165b}, A. Shcherbakova^{147a,147b}, C. Y. Shehu¹⁵⁰, P. Sherwood⁷⁸, L. Shi^{152,ae}, S. Shimizu⁶⁷, C. O. Shimmin¹⁶⁴, M. Shimojima¹⁰², M. Shiyakova⁶⁵, A. Shmeleva⁹⁶, D. Shoaleh Saadi⁹⁵, M. J. Shochet³¹, S. Shojaii^{91a,91b}, S. Shrestha¹¹¹, E. Shulga⁹⁸, M. A. Shupe⁷, S. Shushkevich⁴², P. Sicho¹²⁷, O. Sidiropoulou¹⁷⁵, D. Sidorov¹¹⁴, A. Sidoti^{20a,20b}, F. Siegert⁴⁴, Dj. Sijacki¹³, J. Silva^{126a,126d}, Y. Silver¹⁵⁴, D. Silverstein¹⁴⁴, S. B. Silverstein^{147a}, V. Simak¹²⁸, O. Simard⁵, Lj. Simic¹³, S. Simion¹¹⁷, E. Simioni⁸³, B. Simmons⁷⁸, D. Simon³⁴, R. Simoniello^{91a,91b}, P. Sinervo¹⁵⁹, N. B. Sinev¹¹⁶, G. Siragusa¹⁷⁵, A. Sircar⁷⁹, A. N. Sisakyan^{65,*}, S. Yu. Sivoklov⁹⁹, J. Sjölín^{147a,147b}, T. B. Sjrursen¹⁴, M. B. Skinner⁷², H. P. Skottowe⁵⁷, P. Skubic¹¹³, M. Slater¹⁸, T. Slavicek¹²⁸, M. Slawinska¹⁰⁷, K. Sliwa¹⁶², V. Smakhtin¹⁷³, B. H. Smart⁴⁶, L. Smestad¹⁴, S. Yu. Smirnov⁹⁸, Y. Smirnov⁹⁸, L. N. Smirnova^{99,af}, O. Smirnova⁸¹, K. M. Smith⁵³, M. N. K. Smith³⁵, M. Smizanska⁷², K. Smolek¹²⁸, A. A. Snesarev⁹⁶, G. Snidero⁷⁶, S. Snyder²⁵, R. Sobie^{170,k}, F. Socher⁴⁴, A. Soffer¹⁵⁴, D. A. Soh^{152,ae}, C. A. Solans³⁰

M. Solar¹²⁸, J. Solc¹²⁸, E. Yu. Soldatov⁹⁸, U. Soldevila¹⁶⁸, A. A. Solodkov¹³⁰, A. Soloshenko⁶⁵, O. V. Solovyanov¹³⁰, V. Solovyev¹²³, P. Sommer⁴⁸, H. Y. Song^{33b}, N. Soni¹, A. Sood¹⁵, A. Sopczak¹²⁸, B. Sopko¹²⁸, V. Sopko¹²⁸, V. Sorin¹², D. Sosa^{58b}, M. Sosebee⁸, C. L. Sotiropoulou¹⁵⁵, R. Soualah^{165a,165c}, P. Soueid⁹⁵, A. M. Soukharev^{109,c}, D. South⁴², S. Spagnolo^{73a,73b}, F. Spanò⁷⁷, W. R. Spearman⁵⁷, F. Spettel¹⁰¹, R. Spighi^{20a}, G. Spigo³⁰, L. A. Spiller⁸⁸, M. Spousta¹²⁹, T. Spreitzer¹⁵⁹, R. D. St. Denis^{53,*}, S. Staerz⁴⁴, J. Stahlman¹²², R. Stamen^{58a}, S. Stamm¹⁶, E. Stanecka³⁹, C. Stancu^{135a}, M. Stancu-Bellu⁴², M. M. Stanitzki⁴², S. Stapnes¹¹⁹, E. A. Starchenko¹³⁰, J. Stark⁵⁵, P. Staroba¹²⁷, P. Starovoitov⁴², R. Staszewski³⁹, P. Stavina^{145a,*}, P. Steinberg²⁵, B. Stelzer¹⁴³, H. J. Stelzer³⁰, O. Stelzer-Chilton^{160a}, H. Stenzel⁵², S. Stern¹⁰¹, G. A. Stewart⁵³, J. A. Stillings²¹, M. C. Stockton⁸⁷, M. Stoebe⁸⁷, G. Stoica^{26a}, P. Stolte⁵⁴, S. Stonjek¹⁰¹, A. R. Stradling⁸, A. Straessner⁴⁴, M. E. Stramaglia¹⁷, J. Strandberg¹⁴⁸, S. Strandberg^{147a,147b}, A. Strandlie¹¹⁹, E. Strauss¹⁴⁴, M. Strauss¹¹³, P. Strizenec^{145b}, R. Ströhmer¹⁷⁵, D. M. Strom¹¹⁶, R. Stroynowski⁴⁰, A. Strubig¹⁰⁶, S. A. Stucci¹⁷, B. Stugu¹⁴, N. A. Styles⁴², D. Su¹⁴⁴, J. Su¹²⁵, R. Subramaniam⁷⁹, A. Succurro¹², Y. Sugaya¹¹⁸, C. Suhr¹⁰⁸, M. Suk¹²⁸, V. V. Sulin⁹⁶, S. Sultansoy^{4d}, T. Sumida⁶⁸, S. Sun⁵⁷, X. Sun^{33a}, J. E. Sundermann⁴⁸, K. Suruliz¹⁵⁰, G. Susinno^{37a,37b}, M. R. Sutton¹⁵⁰, Y. Suzuki⁶⁶, M. Svatos¹²⁷, S. Swedish¹⁶⁹, M. Swiatlowski¹⁴⁴, I. Sykora^{145a}, T. Sykora¹²⁹, D. Ta⁹⁰, C. Taccini^{135a,135b}, K. Tackmann⁴², J. Taenzer¹⁵⁹, A. Taffard¹⁶⁴, R. Tafirout^{160a}, N. Taiblum¹⁵⁴, H. Takai²⁵, R. Takashima⁶⁹, H. Takeda⁶⁷, T. Takeshita¹⁴¹, Y. Takubo⁶⁶, M. Talby⁸⁵, A. A. Talyshv^{109,c}, J. Y. C. Tam¹⁷⁵, K. G. Tan⁸⁸, J. Tanaka¹⁵⁶, R. Tanaka¹¹⁷, S. Tanaka¹³², S. Tanaka⁶⁶, A. J. Tanasijczuk¹⁴³, B. B. Tannenwald¹¹¹, N. Tannoury²¹, S. Tapprogge⁸³, S. Tarem¹⁵³, F. Tarrade²⁹, G. F. Tartarelli^{91a}, P. Tas¹²⁹, M. Tasevsky¹²⁷, T. Tashiro⁶⁸, E. Tassi^{37a,37b}, A. Tavares Delgado^{126a,126b}, Y. Tayalati^{136d}, F. E. Taylor⁹⁴, G. N. Taylor⁸⁸, W. Taylor^{160b}, F. A. Teischinger³⁰, M. Teixeira Dias Castanheira⁷⁶, P. Teixeira-Dias⁷⁷, K. K. Temming⁴⁸, H. Ten Kate³⁰, P. K. Teng¹⁵², J. J. Teoh¹¹⁸, F. Tepel¹⁷⁶, S. Terada⁶⁶, K. Terashi¹⁵⁶, J. Terron⁸², S. Terzo¹⁰¹, M. Testa⁴⁷, R. J. Teuscher^{159,k}, J. Therhaag²¹, T. Theveniaux-Pelzer³⁴, J. P. Thomas¹⁸, J. Thomas-Wilsker⁷⁷, E. N. Thompson³⁵, P. D. Thompson¹⁸, R. J. Thompson⁸⁴, A. S. Thompson⁵³, L. A. Thomsen³⁶, E. Thomson¹²², M. Thomson²⁸, W. M. Thong⁸⁸, R. P. Thun^{89,*}, F. Tian³⁵, M. J. Tibbetts¹⁵, R. E. Ticse Torres⁸⁵, V. O. Tikhomirov^{96,ag}, Yu. A. Tikhonov^{109,c}, S. Timoshenko⁹⁸, E. Tiouchichine⁸⁵, P. Tipton¹⁷⁷, S. Tisserant⁸⁵, T. Todorov^{5,*}, S. Todorova-Nova¹²⁹, J. Tojo⁷⁰, S. Tokár^{145a}, K. Tokushuku⁶⁶, K. Tollefson⁹⁰, E. Tolley⁵⁷, L. Tomlinson⁸⁴, M. Tomoto¹⁰³, L. Tompkins^{144,ah}, K. Toms¹⁰⁵, E. Torrence¹¹⁶, H. Torres¹⁴³, E. Torró Pastor¹⁶⁸, J. Toth^{85,ai}, F. Touchard⁸⁵, D. R. Tovey¹⁴⁰, H. L. Tran¹¹⁷, T. Trefzger¹⁷⁵, L. Tremblet³⁰, A. Tricoli³⁰, I. M. Trigger^{160a}, S. Trincaz-Duvoid⁸⁰, M. F. Tripania¹², W. Trischuk¹⁵⁹, B. Trocme⁵⁵, C. Troncon^{91a}, M. Trottier-McDonald¹⁵, M. Trovatielli^{135a,135b}, P. True⁹⁰, M. Trzebinski³⁹, A. Trzupek³⁹, C. Tsarouchas³⁰, J. C.-L. Tseng¹²⁰, P. V. Tsiarshka⁹², D. Tsiou¹⁵⁵, G. Tsipolitis¹⁰, N. Tsirintanis⁹, S. Tsiskaridze¹², V. Tsiskaridze⁴⁸, E. G. Tskhadadze^{51a}, I. I. Tsukerman⁹⁷, V. Tsulaia¹⁵, S. Tsuno⁶⁶, D. Tsybychev¹⁴⁹, A. Tudorache^{26a}, V. Tudorache^{26a}, A. N. Tuna¹²², S. A. Tuppuri^{20a,20b}, S. Turchikhin^{99,af}, D. Turecek¹²⁸, R. Turra^{91a,91b}, A. J. Turvey⁴⁰, P. M. Tuts³⁵, A. Tykhonov⁴⁹, M. Tylmad^{147a,147b}, M. Tyndel¹³¹, I. Ueda¹⁵⁶, R. Ueno²⁹, M. Ughetto^{147a,147b}, M. Ugland¹⁴, M. Uhlenbrock²¹, F. Ukegawa¹⁶¹, G. Unal³⁰, A. Undrus²⁵, G. Unel¹⁶⁴, F. C. Ungaro⁴⁸, Y. Unno⁶⁶, C. Unverdorben¹⁰⁰, J. Urban^{145b}, P. Urquijo⁸⁸, P. Urrejola⁸³, G. Usai⁸, A. Usanova⁶², L. Vacavant⁸⁵, V. Vacek¹²⁸, B. Vachon⁸⁷, N. Valencic¹⁰⁷, S. Valentinetti^{20a,20b}, A. Valero¹⁶⁸, L. Valery¹², S. Valkar¹²⁹, E. Valladolid Gallego¹⁶⁸, S. Vallecorsa⁴⁹, J. A. Valls Ferrer¹⁶⁸, W. Van Den Wollenberg¹⁰⁷, P. C. Van Der Deijl¹⁰⁷, R. van der Geer¹⁰⁷, H. van der Graaf¹⁰⁷, R. Van Der Leeuw¹⁰⁷, N. van Eldik³⁰, P. van Gemmeren⁶, J. Van Nieuwkoop¹⁴³, I. van Vulpen¹⁰⁷, M. C. van Woerden³⁰, M. Vanadia^{133a,133b}, W. Vandelli³⁰, R. Vanguri¹²², A. Vaniachine⁶, F. Vannucci⁸⁰, G. Vardanyan¹⁷⁸, R. Vari^{133a}, E. W. Varnes⁷, T. Varol⁴⁰, D. Varouchas⁸⁰, A. Vartapetian⁸, K. E. Varvell¹⁵¹, F. Vazeille³⁴, T. Vazquez Schroeder⁵⁴, J. Veatch⁷, F. Veloso^{126a,126c}, T. Velz²¹, S. Veneziano^{133a}, A. Ventura^{73a,73b}, D. Ventura⁸⁶, M. Venturi¹⁷⁰, N. Venturi¹⁵⁹, A. Venturini²³, V. Vercesi^{121a}, M. Verducci^{133a,133b}, W. Verkerke¹⁰⁷, J. C. Vermeulen¹⁰⁷, A. Vest⁴⁴, M. C. Vetterli^{143,d}, O. Viazlo⁸¹, I. Vichou¹⁶⁶, T. Vickey^{146c,aj}, O. E. Vickey Boeriu^{146c}, G. H. A. Viehhauser¹²⁰, S. Viel¹⁵, R. Vigne³⁰, M. Villa^{20a,20b}, M. Villaplana Perez^{91a,91b}, E. Vilucchi⁴⁷, M. G. Vincker²⁹, V. B. Vinogradov⁶⁵, I. Vivarelli¹⁵⁰, F. Vives Vaque³, S. Vlachos¹⁰, D. Vladioiu¹⁰⁰, M. Vlasak¹²⁸, M. Vogel^{32a}, P. Vokac¹²⁸, G. Volpi^{124a,124b}, M. Volpi⁸⁸, H. von der Schmitt¹⁰¹, H. von Radziewski⁴⁸, E. von Toerne²¹, V. Vorobel¹²⁹, K. Vorobev⁹⁸, M. Vos¹⁶⁸, R. Voss³⁰, J. H. Vosseveld⁷⁴, N. Vranjes¹³, M. Vranjes Milosavljevic¹³, V. Vrba¹²⁷, M. Vreeswijk¹⁰⁷, R. Vuillermet³⁰, I. Vukotic³¹, Z. Vykydal¹²⁸, P. Wagner²¹, W. Wagner¹⁷⁶, H. Wahlberg⁷¹, S. Wahrmund⁴⁴, J. Wakabayashi¹⁰³, J. Walder⁷², R. Walker¹⁰⁰, W. Walkowiak¹⁴², C. Wang^{33c}, F. Wang¹⁷⁴, H. Wang¹⁵, H. Wang⁴⁰, J. Wang⁴², J. Wang^{33a}, K. Wang⁸⁷, R. Wang¹⁰⁵, S. M. Wang¹⁵², T. Wang²¹, X. Wang¹⁷⁷, C. Wanotayaroj¹¹⁶, A. Warburton⁸⁷, C. P. Ward²⁸, D. R. Wardrope⁷⁸, M. Warsinsky⁴⁸, A. Washbrook⁴⁶, C. Wasicki⁴², P. M. Watkins¹⁸, A. T. Watson¹⁸, I. J. Watson¹⁵¹, M. F. Watson¹⁸, G. Watts¹³⁹, S. Watts⁸⁴, B. M. Waugh⁷⁸, S. Webb⁸⁴, M. S. Weber¹⁷, S. W. Weber¹⁷⁵, J. S. Webster³¹, A. R. Weidberg¹²⁰, B. Weinert⁶¹, J. Weingarten⁵⁴, C. Weiser⁴⁸, H. Weits¹⁰⁷, P. S. Wells³⁰, T. Wenaus²⁵, D. Wendland¹⁶, T. Wengler³⁰, S. Wenig³⁰, N. Wermes²¹, M. Werner⁴⁸, P. Werner³⁰, M. Wessels^{58a}, J. Wetter¹⁶², K. Whalen²⁹, A. M. Wharton⁷², A. White⁸, M. J. White¹, R. White^{32b}, S. White^{124a,124b}, D. Whiteson¹⁶⁴, D. Wicke¹⁷⁶, F. J. Wickens¹³¹, W. Wiedenmann¹⁷⁴,

M. Wielers¹³¹, P. Wienemann²¹, C. Wigglesworth³⁶, L. A. M. Wiik-Fuchs²¹, A. Wildauer¹⁰¹, H. G. Wilkens³⁰, H. H. Williams¹²², S. Williams¹⁰⁷, C. Willis⁹⁰, S. Willocq⁸⁶, A. Wilson⁸⁹, J. A. Wilson¹⁸, I. Wingerter-Seez⁵, F. Winklmeier¹¹⁶, B. T. Winter²¹, M. Wittgen¹⁴⁴, J. Wittkowski¹⁰⁰, S. J. Wollstadt⁸³, M. W. Wolter³⁹, H. Wolters^{126a,126c}, B. K. Wosiek³⁹, J. Wotschack³⁰, M. J. Woudstra⁸⁴, K. W. Wozniak³⁹, M. Wu⁵⁵, M. Wu³¹, S. L. Wu¹⁷⁴, X. Wu⁴⁹, Y. Wu⁸⁹, T. R. Wyatt⁸⁴, B. M. Wynne⁴⁶, S. Xella³⁶, D. Xu^{33a}, L. Xu^{33b,ak}, B. Yabsley¹⁵¹, S. Yacoob^{146b,al}, R. Yakabe⁶⁷, M. Yamada⁶⁶, Y. Yamaguchi¹¹⁸, A. Yamamoto⁶⁶, S. Yamamoto¹⁵⁶, T. Yamanaka¹⁵⁶, K. Yamauchi¹⁰³, Y. Yamazaki⁶⁷, Z. Yan²², H. Yang^{33e}, H. Yang¹⁷⁴, Y. Yang¹⁵², S. Yanush⁹³, L. Yao^{33a}, W.-M. Yao¹⁵, Y. Yasu⁶⁶, E. Yatsenko⁴², K. H. Yau Wong²¹, J. Ye⁴⁰, S. Ye²⁵, I. Yeletsikh⁶⁵, A. L. Yen⁵⁷, E. Yildirim⁴², K. Yorita¹⁷², R. Yoshida⁶, K. Yoshihara¹²², C. Young¹⁴⁴, C. J. S. Young³⁰, S. Youssef²², D. R. Yu¹⁵, J. Yu⁸, J. M. Yu⁸⁹, J. Yu¹¹⁴, L. Yuan⁶⁷, A. Yurkewicz¹⁰⁸, I. Yusuff^{28,am}, B. Zabinski³⁹, R. Zaidan⁶³, A. M. Zaitsev^{130,aa}, A. Zaman¹⁴⁹, S. Zambito²³, L. Zanello^{133a,133b}, D. Zanzi⁸⁸, C. Zeitnitz¹⁷⁶, M. Zeman¹²⁸, A. Zemla^{38a}, K. Zengel²³, O. Zenin¹³⁰, T. Ženiš^{145a}, D. Zerwas¹¹⁷, D. Zhang⁸⁹, F. Zhang¹⁷⁴, J. Zhang⁶, L. Zhang¹⁵², R. Zhang^{33b}, X. Zhang^{33d}, Z. Zhang¹¹⁷, X. Zhao⁴⁰, Y. Zhao^{33d,117}, Z. Zhao^{33b}, A. Zhemchugov⁶⁵, J. Zhong¹²⁰, B. Zhou⁸⁹, C. Zhou⁴⁵, L. Zhou³⁵, L. Zhou⁴⁰, N. Zhou¹⁶⁴, C. G. Zhu^{33d}, H. Zhu^{33a}, J. Zhu⁸⁹, Y. Zhu^{33b}, X. Zhuang^{33a}, K. Zhukov⁹⁶, A. Zibell¹⁷⁵, D. Zieminska⁶¹, N. I. Zimine⁶⁵, C. Zimmermann⁸³, R. Zimmermann²¹, S. Zimmermann⁴⁸, Z. Zinonos⁵⁴, M. Zinser⁸³, M. Ziolkowski¹⁴², L. Živković¹³, G. Zobernig¹⁷⁴, A. Zoccoli^{20a,20b}, M. zur Nedden¹⁶, G. Zurzolo^{104a,104b}, L. Zwalinski³⁰

¹ Department of Physics, University of Adelaide, Adelaide, Australia

² Physics Department, SUNY Albany, Albany, NY, USA

³ Department of Physics, University of Alberta, Edmonton, AB, Canada

⁴ (a) Department of Physics, Ankara University, Ankara, Turkey; (c) Istanbul Aydin University, Istanbul, Turkey;

(d) Division of Physics, TOBB University of Economics and Technology, Ankara, Turkey

⁵ LAPP, CNRS/IN2P3 and Université Savoie Mont Blanc, Annecy-le-Vieux, France

⁶ High Energy Physics Division, Argonne National Laboratory, Argonne, IL, USA

⁷ Department of Physics, University of Arizona, Tucson, AZ, USA

⁸ Department of Physics, The University of Texas at Arlington, Arlington, TX, USA

⁹ Physics Department, University of Athens, Athens, Greece

¹⁰ Physics Department, National Technical University of Athens, Zografou, Greece

¹¹ Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan

¹² Institut de Física d'Altes Energies and Departament de Física de la Universitat Autònoma de Barcelona, Barcelona, Spain

¹³ Institute of Physics, University of Belgrade, Belgrade, Serbia

¹⁴ Department for Physics and Technology, University of Bergen, Bergen, Norway

¹⁵ Physics Division, Lawrence Berkeley National Laboratory and University of California, Berkeley, CA, USA

¹⁶ Department of Physics, Humboldt University, Berlin, Germany

¹⁷ Albert Einstein Center for Fundamental Physics and Laboratory for High Energy Physics, University of Bern, Bern, Switzerland

¹⁸ School of Physics and Astronomy, University of Birmingham, Birmingham, UK

¹⁹ (a) Department of Physics, Bogazici University, Istanbul, Turkey; (b) Department of Physics, Dogus University, Istanbul, Turkey; (c) Department of Physics Engineering, Gaziantep University, Gaziantep, Turkey

²⁰ (a) INFN Sezione di Bologna, Bologna, Italy; (b) Dipartimento di Fisica e Astronomia, Università di Bologna, Bologna, Italy

²¹ Physikalisches Institut, University of Bonn, Bonn, Germany

²² Department of Physics, Boston University, Boston, MA, USA

²³ Department of Physics, Brandeis University, Waltham, MA, USA

²⁴ (a) Universidade Federal do Rio De Janeiro COPPE/EE/IF, Rio de Janeiro, Brazil; (b) Electrical Circuits Department, Federal University of Juiz de Fora (UFJF), Juiz de Fora, Brazil; (c) Federal University of Sao Joao del Rei (UFSJ), Sao Joao del Rei, Brazil; (d) Instituto de Fisica, Universidade de Sao Paulo, São Paulo, Brazil

²⁵ Physics Department, Brookhaven National Laboratory, Upton, NY, USA

²⁶ (a) National Institute of Physics and Nuclear Engineering, Bucharest, Romania; (b) Physics Department, National Institute for Research and Development of Isotopic and Molecular Technologies, Cluj Napoca, Romania; (c) University Politehnica Bucharest, Bucharest, Romania; (d) West University in Timisoara, Timisoara, Romania

²⁷ Departamento de Física, Universidad de Buenos Aires, Buenos Aires, Argentina

²⁸ Cavendish Laboratory, University of Cambridge, Cambridge, UK

- ²⁹ Department of Physics, Carleton University, Ottawa, ON, Canada
- ³⁰ CERN, Geneva, Switzerland
- ³¹ Enrico Fermi Institute, University of Chicago, Chicago, IL, USA
- ³² ^(a)Departamento de Física, Pontificia Universidad Católica de Chile, Santiago, Chile; ^(b)Departamento de Física, Universidad Técnica Federico Santa María, Valparaíso, Chile
- ³³ ^(a)Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China; ^(b)Department of Modern Physics, University of Science and Technology of China, Anhui, China; ^(c)Department of Physics, Nanjing University, Jiangsu, China; ^(d)School of Physics, Shandong University, Shandong, China; ^(e)Department of Physics and Astronomy, Shanghai Key Laboratory for Particle Physics and Cosmology, Shanghai Jiao Tong University, Shanghai, China; ^(f)Physics Department, Tsinghua University, 100084 Beijing, China
- ³⁴ Laboratoire de Physique Corpusculaire, Clermont Université and Université Blaise Pascal and CNRS/IN2P3, Clermont-Ferrand, France
- ³⁵ Nevis Laboratory, Columbia University, Irvington, NY, USA
- ³⁶ Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark
- ³⁷ ^(a)INFN Gruppo Collegato di Cosenza, Laboratori Nazionali di Frascati, Italy; ^(b)Dipartimento di Fisica, Università della Calabria, Rende, Italy
- ³⁸ ^(a)Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Kraków, Poland; ^(b)Marian Smoluchowski Institute of Physics, Jagiellonian University, Kraków, Poland
- ³⁹ Institute of Nuclear Physics, Polish Academy of Sciences, Kraków, Poland
- ⁴⁰ Physics Department, Southern Methodist University, Dallas, TX, USA
- ⁴¹ Physics Department, University of Texas at Dallas, Richardson, TX, USA
- ⁴² DESY, Hamburg and Zeuthen, Germany
- ⁴³ Institut für Experimentelle Physik IV, Technische Universität Dortmund, Dortmund, Germany
- ⁴⁴ Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Dresden, Germany
- ⁴⁵ Department of Physics, Duke University, Durham, NC, USA
- ⁴⁶ SUPA-School of Physics and Astronomy, University of Edinburgh, Edinburgh, UK
- ⁴⁷ INFN Laboratori Nazionali di Frascati, Frascati, Italy
- ⁴⁸ Fakultät für Mathematik und Physik, Albert-Ludwigs-Universität, Freiburg, Germany
- ⁴⁹ Section de Physique, Université de Genève, Geneva, Switzerland
- ⁵⁰ ^(a)INFN Sezione di Genova, Genoa, Italy; ^(b)Dipartimento di Fisica, Università di Genova, Genoa, Italy
- ⁵¹ ^(a)E. Andronikashvili Institute of Physics, Iv. Javakishvili Tbilisi State University, Tbilisi, Georgia; ^(b)High Energy Physics Institute, Tbilisi State University, Tbilisi, Georgia
- ⁵² II Physikalisches Institut, Justus-Liebig-Universität Giessen, Giessen, Germany
- ⁵³ SUPA-School of Physics and Astronomy, University of Glasgow, Glasgow, UK
- ⁵⁴ II Physikalisches Institut, Georg-August-Universität, Göttingen, Germany
- ⁵⁵ Laboratoire de Physique Subatomique et de Cosmologie, Université Grenoble-Alpes, CNRS/IN2P3, Grenoble, France
- ⁵⁶ Department of Physics, Hampton University, Hampton, VA, USA
- ⁵⁷ Laboratory for Particle Physics and Cosmology, Harvard University, Cambridge, MA, USA
- ⁵⁸ ^(a)Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany; ^(b)Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany; ^(c)ZITI Institut für technische Informatik, Ruprecht-Karls-Universität Heidelberg, Mannheim, Germany
- ⁵⁹ Faculty of Applied Information Science, Hiroshima Institute of Technology, Hiroshima, Japan
- ⁶⁰ ^(a)Department of Physics, The Chinese University of Hong Kong, Shatin, NT, Hong Kong; ^(b)Department of Physics, The University of Hong Kong, Pok Fu Lam, Hong Kong; ^(c)Department of Physics, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, China
- ⁶¹ Department of Physics, Indiana University, Bloomington, IN, USA
- ⁶² Institut für Astro- und Teilchenphysik, Leopold-Franzens-Universität, Innsbruck, Austria
- ⁶³ University of Iowa, Iowa City, IA, USA
- ⁶⁴ Department of Physics and Astronomy, Iowa State University, Ames, IA, USA
- ⁶⁵ Joint Institute for Nuclear Research, JINR Dubna, Dubna, Russia
- ⁶⁶ KEK, High Energy Accelerator Research Organization, Tsukuba, Japan
- ⁶⁷ Graduate School of Science, Kobe University, Kobe, Japan
- ⁶⁸ Faculty of Science, Kyoto University, Kyoto, Japan

- ⁶⁹ Kyoto University of Education, Kyoto, Japan
- ⁷⁰ Department of Physics, Kyushu University, Fukuoka, Japan
- ⁷¹ Instituto de Física La Plata, Universidad Nacional de La Plata and CONICET, La Plata, Argentina
- ⁷² Physics Department, Lancaster University, Lancaster, UK
- ⁷³ ^(a)INFN Sezione di Lecce, Lecce, Italy; ^(b)Dipartimento di Matematica e Fisica, Università del Salento, Lecce, Italy
- ⁷⁴ Oliver Lodge Laboratory, University of Liverpool, Liverpool, UK
- ⁷⁵ Department of Physics, Jožef Stefan Institute and University of Ljubljana, Ljubljana, Slovenia
- ⁷⁶ School of Physics and Astronomy, Queen Mary University of London, London, UK
- ⁷⁷ Department of Physics, Royal Holloway University of London, Surrey, UK
- ⁷⁸ Department of Physics and Astronomy, University College London, London, UK
- ⁷⁹ Louisiana Tech University, Ruston, LA, USA
- ⁸⁰ Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France
- ⁸¹ Fysiska institutionen, Lunds universitet, Lund, Sweden
- ⁸² Departamento de Física Teórica C-15, Universidad Autónoma de Madrid, Madrid, Spain
- ⁸³ Institut für Physik, Universität Mainz, Mainz, Germany
- ⁸⁴ School of Physics and Astronomy, University of Manchester, Manchester, UK
- ⁸⁵ CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
- ⁸⁶ Department of Physics, University of Massachusetts, Amherst, MA, USA
- ⁸⁷ Department of Physics, McGill University, Montreal, QC, Canada
- ⁸⁸ School of Physics, University of Melbourne, Melbourne, VIC, Australia
- ⁸⁹ Department of Physics, The University of Michigan, Ann Arbor, MI, USA
- ⁹⁰ Department of Physics and Astronomy, Michigan State University, East Lansing, MI, USA
- ⁹¹ ^(a)INFN Sezione di Milano, Milan, Italy; ^(b)Dipartimento di Fisica, Università di Milano, Milan, Italy
- ⁹² B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Republic of Belarus
- ⁹³ National Scientific and Educational Centre for Particle and High Energy Physics, Minsk, Republic of Belarus
- ⁹⁴ Department of Physics, Massachusetts Institute of Technology, Cambridge, MA, USA
- ⁹⁵ Group of Particle Physics, University of Montreal, Montreal, QC, Canada
- ⁹⁶ P.N. Lebedev Institute of Physics, Academy of Sciences, Moscow, Russia
- ⁹⁷ Institute for Theoretical and Experimental Physics (ITEP), Moscow, Russia
- ⁹⁸ National Research Nuclear University MEPhI, Moscow, Russia
- ⁹⁹ D.V. Skobel'syn Institute of Nuclear Physics, M.V. Lomonosov Moscow State University, Moscow, Russia
- ¹⁰⁰ Fakultät für Physik, Ludwig-Maximilians-Universität München, Munich, Germany
- ¹⁰¹ Max-Planck-Institut für Physik (Werner-Heisenberg-Institut), Munich, Germany
- ¹⁰² Nagasaki Institute of Applied Science, Nagasaki, Japan
- ¹⁰³ Graduate School of Science and Kobayashi-Maskawa Institute, Nagoya University, Nagoya, Japan
- ¹⁰⁴ ^(a)INFN Sezione di Napoli, Naples, Italy; ^(b)Dipartimento di Fisica, Università di Napoli, Naples, Italy
- ¹⁰⁵ Department of Physics and Astronomy, University of New Mexico, Albuquerque, NM, USA
- ¹⁰⁶ Institute for Mathematics, Astrophysics and Particle Physics, Radboud University Nijmegen/Nikhef, Nijmegen, The Netherlands
- ¹⁰⁷ Nikhef National Institute for Subatomic Physics and University of Amsterdam, Amsterdam, The Netherlands
- ¹⁰⁸ Department of Physics, Northern Illinois University, De Kalb, IL, USA
- ¹⁰⁹ Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, Russia
- ¹¹⁰ Department of Physics, New York University, New York, NY, USA
- ¹¹¹ Ohio State University, Columbus, OH, USA
- ¹¹² Faculty of Science, Okayama University, Okayama, Japan
- ¹¹³ Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, OK, USA
- ¹¹⁴ Department of Physics, Oklahoma State University, Stillwater, OK, USA
- ¹¹⁵ Palacký University, RCPTM, Olomouc, Czech Republic
- ¹¹⁶ Center for High Energy Physics, University of Oregon, Eugene, OR, USA
- ¹¹⁷ LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France
- ¹¹⁸ Graduate School of Science, Osaka University, Osaka, Japan
- ¹¹⁹ Department of Physics, University of Oslo, Oslo, Norway

- ¹²⁰ Department of Physics, Oxford University, Oxford, UK
- ¹²¹ ^(a) INFN Sezione di Pavia, Pavia, Italy; ^(b) Dipartimento di Fisica, Università di Pavia, Pavia, Italy
- ¹²² Department of Physics, University of Pennsylvania, Philadelphia, PA, USA
- ¹²³ Petersburg Nuclear Physics Institute, Gatchina, Russia
- ¹²⁴ ^(a) INFN Sezione di Pisa, Pisa, Italy; ^(b) Dipartimento di Fisica E. Fermi, Università di Pisa, Pisa, Italy
- ¹²⁵ Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, PA, USA
- ¹²⁶ ^(a) Laboratório de Instrumentação e Física Experimental de Partículas-LIP, Lisbon, Portugal; ^(b) Faculdade de Ciências, Universidade de Lisboa, Lisbon, Portugal; ^(c) Department of Physics, University of Coimbra, Coimbra, Portugal; ^(d) Centro de Física Nuclear da Universidade de Lisboa, Lisbon, Portugal; ^(e) Departamento de Física, Universidade do Minho, Braga, Portugal; ^(f) Departamento de Física Teórica y del Cosmos and CAFPE, Universidad de Granada, Granada, Spain; ^(g) Dep Física and CEFITEC of Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal
- ¹²⁷ Institute of Physics, Academy of Sciences of the Czech Republic, Prague, Czech Republic
- ¹²⁸ Czech Technical University in Prague, Prague, Czech Republic
- ¹²⁹ Faculty of Mathematics and Physics, Charles University in Prague, Prague, Czech Republic
- ¹³⁰ State Research Center Institute for High Energy Physics, Protvino, Russia
- ¹³¹ Particle Physics Department, Rutherford Appleton Laboratory, Didcot, UK
- ¹³² Ritsumeikan University, Kusatsu, Shiga, Japan
- ¹³³ ^(a) INFN Sezione di Roma, Rome, Italy; ^(b) Dipartimento di Fisica, Sapienza Università di Roma, Rome, Italy
- ¹³⁴ ^(a) INFN Sezione di Roma Tor Vergata, Rome, Italy; ^(b) Dipartimento di Fisica, Università di Roma Tor Vergata, Rome, Italy
- ¹³⁵ ^(a) INFN Sezione di Roma Tre, Rome, Italy; ^(b) Dipartimento di Matematica e Fisica, Università Roma Tre, Rome, Italy
- ¹³⁶ ^(a) Faculté des Sciences Ain Chock, Réseau Universitaire de Physique des Hautes Energies-Université Hassan II, Casablanca, Morocco; ^(b) Centre National de l'Energie des Sciences Techniques Nucleaires, Rabat, Morocco; ^(c) Faculté des Sciences Semlalia, Université Cadi Ayyad, LPHEA-Marrakech, Marrakech, Morocco; ^(d) Faculté des Sciences, Université Mohamed Premier and LPTPM, Oujda, Morocco; ^(e) Faculté des Sciences, Université Mohammed V-Agdal, Rabat, Morocco
- ¹³⁷ DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l'Univers), CEA Saclay (Commissariat à l'Energie Atomique et aux Energies Alternatives), Gif-sur-Yvette, France
- ¹³⁸ Santa Cruz Institute for Particle Physics, University of California Santa Cruz, Santa Cruz, CA, USA
- ¹³⁹ Department of Physics, University of Washington, Seattle, WA, USA
- ¹⁴⁰ Department of Physics and Astronomy, University of Sheffield, Sheffield, UK
- ¹⁴¹ Department of Physics, Shinshu University, Nagano, Japan
- ¹⁴² Fachbereich Physik, Universität Siegen, Siegen, Germany
- ¹⁴³ Department of Physics, Simon Fraser University, Burnaby, BC, Canada
- ¹⁴⁴ SLAC National Accelerator Laboratory, Stanford, CA, USA
- ¹⁴⁵ ^(a) Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava, Slovak Republic; ^(b) Department of Subnuclear Physics, Institute of Experimental Physics of the Slovak Academy of Sciences, Kosice, Slovak Republic
- ¹⁴⁶ ^(a) Department of Physics, University of Cape Town, Cape Town, South Africa; ^(b) Department of Physics, University of Johannesburg, Johannesburg, South Africa; ^(c) School of Physics, University of the Witwatersrand, Johannesburg, South Africa
- ¹⁴⁷ ^(a) Department of Physics, Stockholm University, Stockholm, Sweden; ^(b) The Oskar Klein Centre, Stockholm, Sweden
- ¹⁴⁸ Physics Department, Royal Institute of Technology, Stockholm, Sweden
- ¹⁴⁹ Departments of Physics and Astronomy and Chemistry, Stony Brook University, Stony Brook, NY, USA
- ¹⁵⁰ Department of Physics and Astronomy, University of Sussex, Brighton, UK
- ¹⁵¹ School of Physics, University of Sydney, Sydney, Australia
- ¹⁵² Institute of Physics, Academia Sinica, Taipei, Taiwan
- ¹⁵³ Department of Physics, Technion: Israel Institute of Technology, Haifa, Israel
- ¹⁵⁴ Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel
- ¹⁵⁵ Department of Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece
- ¹⁵⁶ International Center for Elementary Particle Physics and Department of Physics, The University of Tokyo, Tokyo, Japan
- ¹⁵⁷ Graduate School of Science and Technology, Tokyo Metropolitan University, Tokyo, Japan
- ¹⁵⁸ Department of Physics, Tokyo Institute of Technology, Tokyo, Japan

- ¹⁵⁹ Department of Physics, University of Toronto, Toronto, ON, Canada
- ¹⁶⁰ (a) TRIUMF, Vancouver, BC, Canada; (b) Department of Physics and Astronomy, York University, Toronto, ON, Canada
- ¹⁶¹ Faculty of Pure and Applied Sciences, University of Tsukuba, Tsukuba, Japan
- ¹⁶² Department of Physics and Astronomy, Tufts University, Medford, MA, USA
- ¹⁶³ Centro de Investigaciones, Universidad Antonio Narino, Bogotá, Colombia
- ¹⁶⁴ Department of Physics and Astronomy, University of California Irvine, Irvine, CA, USA
- ¹⁶⁵ (a) INFN Gruppo Collegato di Udine, Sezione di Trieste, Udine, Italy; (b) ICTP, Trieste, Italy; (c) Dipartimento di Chimica, Fisica e Ambiente, Università di Udine, Udine, Italy
- ¹⁶⁶ Department of Physics, University of Illinois, Urbana, IL, USA
- ¹⁶⁷ Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden
- ¹⁶⁸ Instituto de Física Corpuscular (IFIC) and Departamento de Física Atómica, Molecular y Nuclear and Departamento de Ingeniería Electrónica and Instituto de Microelectrónica de Barcelona (IMB-CNM), University of Valencia and CSIC, Valencia, Spain
- ¹⁶⁹ Department of Physics, University of British Columbia, Vancouver, BC, Canada
- ¹⁷⁰ Department of Physics and Astronomy, University of Victoria, Victoria, BC, Canada
- ¹⁷¹ Department of Physics, University of Warwick, Coventry, UK
- ¹⁷² Waseda University, Tokyo, Japan
- ¹⁷³ Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel
- ¹⁷⁴ Department of Physics, University of Wisconsin, Madison, WI, USA
- ¹⁷⁵ Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany
- ¹⁷⁶ Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany
- ¹⁷⁷ Department of Physics, Yale University, New Haven, CT, USA
- ¹⁷⁸ Yerevan Physics Institute, Yerevan, Armenia
- ¹⁷⁹ Centre de Calcul de l'Institut National de Physique Nucléaire et de Physique des Particules (IN2P3), Villeurbanne, France
- ^a Also at Department of Physics, King's College London, London, UK
- ^b Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan
- ^c Also at Novosibirsk State University, Novosibirsk, Russia
- ^d Also at TRIUMF, Vancouver, BC, Canada
- ^e Also at Department of Physics, California State University, Fresno, CA, USA
- ^f Also at Department of Physics, University of Fribourg, Fribourg, Switzerland
- ^g Also at Departamento de Física e Astronomia, Faculdade de Ciências, Universidade do Porto, Porto, Portugal
- ^h Also at Tomsk State University, Tomsk, Russia
- ⁱ Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France
- ^j Also at Università di Napoli Parthenope, Naples, Italy
- ^k Also at Institute of Particle Physics (IPP), Victoria, Canada
- ^l Also at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, UK
- ^m Also at Department of Physics, St. Petersburg State Polytechnical University, St. Petersburg, Russia
- ⁿ Also at Louisiana Tech University, Ruston, LA, USA
- ^o Also at Institutio Catalana de Recerca i Estudis Avancats, ICREA, Barcelona, Spain
- ^p Also at Department of Physics, National Tsing Hua University, Hsinchu, Taiwan
- ^q Also at Department of Physics, The University of Texas at Austin, Austin, TX, USA
- ^r Also at Institute of Theoretical Physics, Ilia State University, Tbilisi, Georgia
- ^s Also at CERN, Geneva, Switzerland
- ^t Also at Georgian Technical University (GTU), Tbilisi, Georgia
- ^u Also at O Chadai Academic Production, Ochanomizu University, Tokyo, Japan
- ^v Also at Manhattan College, New York, NY, USA
- ^w Also at Institute of Physics, Academia Sinica, Taipei, Taiwan
- ^x Also at LAL, Université Paris-Sud and CNRS/IN2P3, Orsay, France
- ^y Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan

- ^z Also at Dipartimento di Fisica, Sapienza Università di Roma, Rome, Italy
- ^{aa} Also at Moscow Institute of Physics and Technology State University, Dolgoprudny, Russia
- ^{ab} Also at Section de Physique, Université de Genève, Geneva, Switzerland
- ^{ac} Also at International School for Advanced Studies (SISSA), Trieste, Italy
- ^{ad} Also at Department of Physics and Astronomy, University of South Carolina, Columbia, SC, USA
- ^{ae} Also at School of Physics and Engineering, Sun Yat-sen University, Guangzhou, China
- ^{af} Also at Faculty of Physics, M.V. Lomonosov Moscow State University, Moscow, Russia
- ^{ag} Also at National Research Nuclear University MEPhI, Moscow, Russia
- ^{ah} Also at Department of Physics, Stanford University, Stanford, CA, USA
- ^{ai} Also at Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Budapest, Hungary
- ^{aj} Also at Department of Physics, Oxford University, Oxford, UK
- ^{ak} Also at Department of Physics, The University of Michigan, Ann Arbor, MI, USA
- ^{al} Also at Discipline of Physics, University of KwaZulu-Natal, Durban, South Africa
- ^{am} Also at University of Malaya, Department of Physics, Kuala Lumpur, Malaysia
- * Deceased